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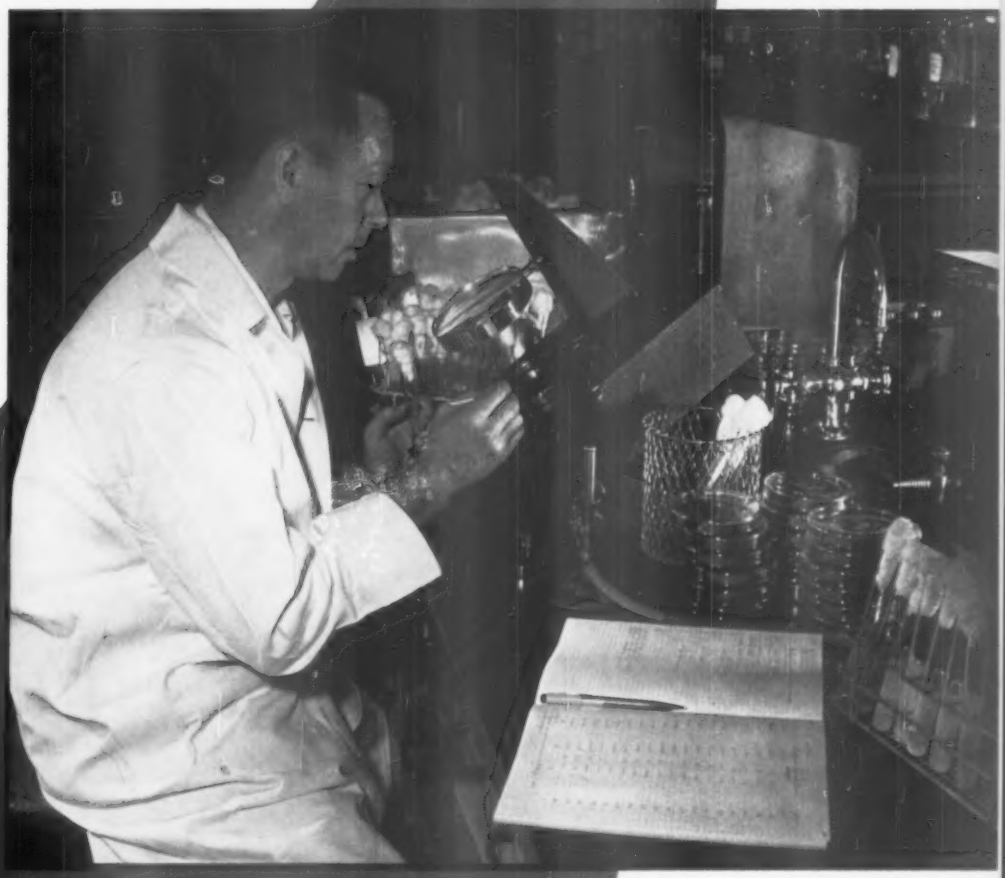
FT food technology



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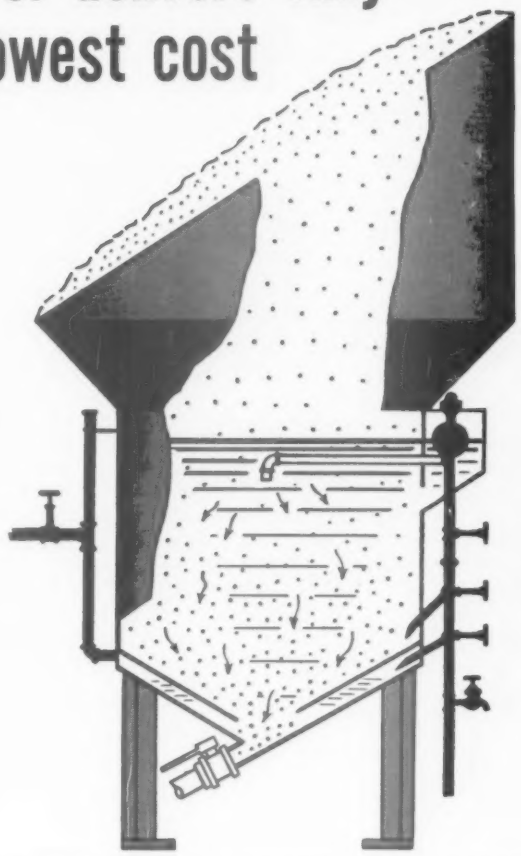

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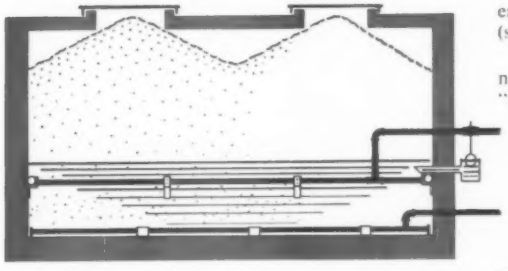

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IN THIS ISSUE–

THE TECHNICAL ARTICLES IN BRIEF

Tenderness tests *Poultry meat*

Post-mortem aging of poultry meat and its effect on tenderness of the breast muscles. John Wesley Dodge and W. J. Stadelman.

Five experiments, involving a total of 456 chickens and 48 turkeys, were conducted. Experiments were designed to measure the effects of different temperatures, media, classes of poultry, age of poultry, and time of aging on post-mortem tenderness of poultry meat. Before testing, all birds were slaughtered, picked, and eviscerated. Carefully controlled, commonly accepted techniques were used. Carcasses were aged in air, water, and high concentrations of ozone at given temperatures for designated time periods after death. After aging carcasses were wrapped in aluminum foil and roasted in a reel type electric oven. The cooked meat was cooled for 20 minutes before uniform samples were cut from each side of the breast, weighed in grams, and tested for tenderness on a Kramer Shear press. The resulting data were analyzed for significance by analysis of variance. Within the limits of this study, the following results were obtained. Age of bird slaughtered, time of aging, class of poultry, temperature of aging, and media in which the carcasses were aged, all appear to be important factors in post-mortem tenderization. Age of the bird slaughtered and the class of poultry appear to be more closely related to actual pattern of rigor. The time of aging and the media appear to be more closely related to level of tenderness within the rigor pattern. The temperature appears to affect both pattern of rigor and level of tenderness at a given time post-mortem. (See page 81.)

Taste test *Thresholds for sodium benzoate, sodium sorbate*

Taste thresholds for sodium benzoate and sodium sorbate in apple cider. E. C. Dryden and Claude H. Hills.

Taste thresholds of sodium benzoate and sodium sorbate in fresh apple cider were determined by means of a trained taste panel, using triangle tests at various levels. The panel was able to detect sodium benzoate at a level of 0.03%. The threshold for sodium sorbate was somewhat higher. Sodium benzoate samples from various manufacturers were compared. A consumer preference type test was also carried out to determine whether the taste of sodium benzoate and that of sodium sorbate were objectionable at the levels commonly used for the preservation of cider. (See page 84.)

Enzymology *Ficin*

Properties of the milk clotting activity of ficin. John R. Whitaker.

Ficin, the proteolytic enzyme(s) of fig latex, has been shown to have properties which make it suitable for use as a meat tenderizer and a clarifier of beverages. It also produces a rapid coagulation of milk. This latter property of ficin is of great potential importance in certain countries where there are objections to slaughtering calves for the production of rennin. Therefore, it is of importance to determine the properties of the component of ficin responsible for milk coagulation and whether this component differs from the component responsible for the proteolytic activity. This work was divided into 2 phases, effect of changes in the substrate solution and effect of changes in the enzyme on the milk coagulating ability of ficin. Effect of the substrate concentration, volume of substrate, volume of sample added, pH of the substrate, addition of calcium ions, and buffer concentration on the milk clotting time are discussed. Effect of temperature (0°–60° C.) on the milk clotting activity and the stability of the milk clotting component as well as the effect of enzyme concentration on the time of clotting have also been determined. Action of some 20 activators and inhibitors of the milk clotting activity of ficin are discussed in terms of the concentration required for half-inactivation or half-activation (I_{50} values). Effect of sorbic acid is especially interesting because of its usefulness in the food industry as a preservative. (See page 86.)

Detection of off-flavor *Formation of PCA in beet puree*

Formation of pyrrolidonecarboxylic acid during the production of beet puree. R. S. Shallenberger, H. R. Pallesen, and J. C. Moyer.

Pyrrolidonecarboxylic acid (PCA) is an important component of an off-flavor which may develop in beet puree during production. The precursor to PCA is the labile amide, glutamine. In order to obtain information upon the formation of PCA in beet purees so that adequate control measures might be recommended, the effect of processing time, processing temperature, and the glutamine concentration were studied. Beet puree was produced in the pilot plant. The holding time, holding temperature, and glutamine content of the mash were varied. The PCA content of the puree was found to be directly related to the holding time and the initial glutamine content, but it varied exponentially with the holding temperature. (See page 92.)

Radiation preservation *Milk, milk products*

Radiation preservation of milk and milk products. VIII. Radiation-distillation apparatus for using high energy electrons. J. H. Wertheim, J. E. Hoff, B. E. Proctor, S. A. Goldblith, R. N. Roychoudhury, and G. D. Saravacos.

February Cover. Bacteriologists maintain continuous checks on the quality of foods. The cover picture for February (courtesy, General Foods Corporation, Birds Eye Division) shows a bacteriologist making bacteria counts, using differential media, on frozen foods.

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An apparatus for the concurrent radiation distillation of milk using high energy electrons from a resonant transformer is described. Preliminary data are presented on comparative studies of milk treated by this means, using electrons and gamma rays from a Cobalt-60 source. (See page 94.)

Colorimetric method *Citral content of lemon oil*

Effects of environmental and processing factors on the citral content of lemon oil. W. L. Stanley and S. H. Vannier.

Evaluating the flavoring quality of fruits and fruit products has been hampered by the lack of selective analytical methods to determine the nature and amounts of the individual flavoring components. This is particularly true for citrus oils in which the flavoring and aromatic components are mainly oxygenated terpenes. The characteristic flavor and aroma of lemon oil are imparted by the terpene aldehyde, citral. However, other aldehydes also are present in undetermined amounts. One of the quality tests currently applied to lemon oils consists of analyzing for total carbonyls (as citral) by the phenylhydrazine method. A new specific colorimetric method of analysis for citral employing vanillin-piperdine reagent has been developed. This method has been applied to a study of the efficiency of commercial processes of recovery and refining in retaining maximum citral content in lemon oil. Results indicated that major losses occur during the pressing of the peel. In this step losses may be as high as 50%. Leaching of citral from the peel by excessive water washing was shown to be negligible, whereas losses during centrifugation were at a minimum. The new method has been applied to a study of the citral content of oils collected directly from the oil glands (flavedo) of the lemon fruit. Variations of citral concentrations in oil samples extracted over the surface of the individual fruit (distribution profile) from fruit collected from different growing areas, fruit of different maturities, from fruit picked from different parts of the tree, and from fruit exposed to sun and shade have been determined. (See page 96.)

Freezing, defrosting *Cakes*

Studies on the freezing and defrosting of cakes. J. W. Pence, M. M. Hanamoto, and J. M. Galbreath.

Time-temperature curves for freezing and defrosting several types of cake were determined over a range of experimental conditions considered to be representative of commercial practice. Effects of temperature, air velocity, and packaging are presented and discussed for iced and plain chocolate and yellow layer cakes, angel food, chiffon, and pound cakes. At both 0° and −20° F., air moving at 650 linear f.p.m. reduced freezing times of unwrapped cakes to a much greater extent than when the cakes were wrapped or packaged. Snug cellophane, corrugated glassine, or foil packaging had less effect on freezing or defrosting times than typical paperboard cake boxes. Icings on layer cakes prolonged freezing and defrosting nearly as much as when cakes without icings were packaged in paperboard boxes. Butter cream icings offered greater resistance to heat flow than fudge type icings. Chiffon cakes froze and defrosted more slowly than angel food cakes of the same size under the same conditions. An increase in temperature from 80° to 100° F. shortened defrosting times to a greater extent than an equal increase from 100° to 120° F. Flavor and texture qualities of cakes were unaffected by variations in freezing and defrosting times ranging from 2 to about 12 hours. (See page 99.)

Consumer preference *Sugar level in ice cream*

The influence of sugar in ice cream. II. Consumer preferences for strawberry ice cream. Rose Marie Pangborn and T. A. Nickerson.

Strawberry ice cream varying in sugar content (15.9%, 17.6%, 19.2% or 20.8%) was evaluated by 650 individuals in a household consumer survey employing the method of paired comparison-preference. Both the consumer panel and a trained laboratory panel preferred the sample containing 19.2% sugar to a significant degree over the other samples. Reasons most frequently given for preferring the sweeter samples were (a) more flavorful, (b) richer, (c) creamier. The majority of the homemakers interviewed indicated that they were willing to pay 5¢ per pint extra for the sample their family preferred. If adjusting the sugar content of ice cream results in a more flavorful product that the majority of the consumers like and are willing to pay extra then a reappraisal of the sweetness levels used in the ice cream industry seems to be in order. (See page 107.)

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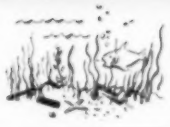

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Defrosting, ultrasonic *Frozen foods*

Ultrasonic defrosting of frozen foods. Aaron L. Brody and G. N. Antonevich.

Vibratory energy at frequencies of 10 kc, 20 kc, 400 kc, and 1000 kc was used in an attempt to accelerate thawing of three representative frozen foods, hamburger, strawberries, and liquid whole egg. Thawed material was more absorptive than frozen material, and so excessive local heating was observed in thawing hamburger. In strawberries which were frozen in sirup, micro-agitation caused by ultrasonic energy increased the rate of heat transfer and minimized localized heating. This streaming effect was very pronounced in liquid whole eggs, allowing for significant increases in thawing rates. High energy requirements for practical thawing rates in frozen liquids and negligible effects in solid foods indicate limitations of ultrasonic energy for thawing. Ultrasonic defrosting does not appear feasible at present because of poor absorption characteristics of foods, lack of practical means to couple energy to food, and high equipment costs. (See page 109.)

Storage study *Orange juice powder*

Orange juice powder. S. K. Notter, D. H. Taylor, and N. J. Downes.

Vacuum-dried orange juice powder containing no additive other than $NaHSO_3$ was stored at 70, 77, and 100° F. Changes in flavor and chemical composition were evaluated at intervals during storage. The stability of the entrapped cold-pressed orange oil was excellent whether in sorbitol, sucrose, or dextrose. Powders containing up to 0.11% free oil were equal in storage stability to those containing .058%. The vacuum-packed powder, after 70° F. storage for one year, was equal in flavor to the −30° F. control, when compared by ranking. The triangle taste test showed the 3-month 70° F. sample to be different from the −30° F. control. After 30 days at 100° F. the sample was judged to be different from the −30° F. control. The IPD dessication rates of orange juice powder at 70° and 77° F. were about 10% greater in 6-oz. than in No. 10 cans. Location of the desiccant in the No. 10 can had no significant effect on desiccation rate of the powder. Loss of SO_2 in orange juice without other additive occurred only in the drying process. The consistency of the juice was unaffected and the color but slightly affected by the drying and storage operations. Under the most adverse conditions used (6 months at 100° F.) 75% of the ascorbic acid was retained. (See page 113.)

Antibiotics *Activity against yeasts and molds*

The effect of several antifungal antibiotics on the growth of common food spoilage fungi. John B. Klis, Lloyd D. Witter, and Z. John Ordal.

The activity spectra of six antifungal antibiotics and sorbic acid against sixteen yeasts and molds responsible for the spoilage of foods was determined. Two testing procedures, an agar plate method and a shake culture method, were used and compared. Of the antifungal antibiotics tested, myprozine had the greatest range of activity at the lowest concentrations. The other antibiotics arranged in order of decreasing effectiveness were

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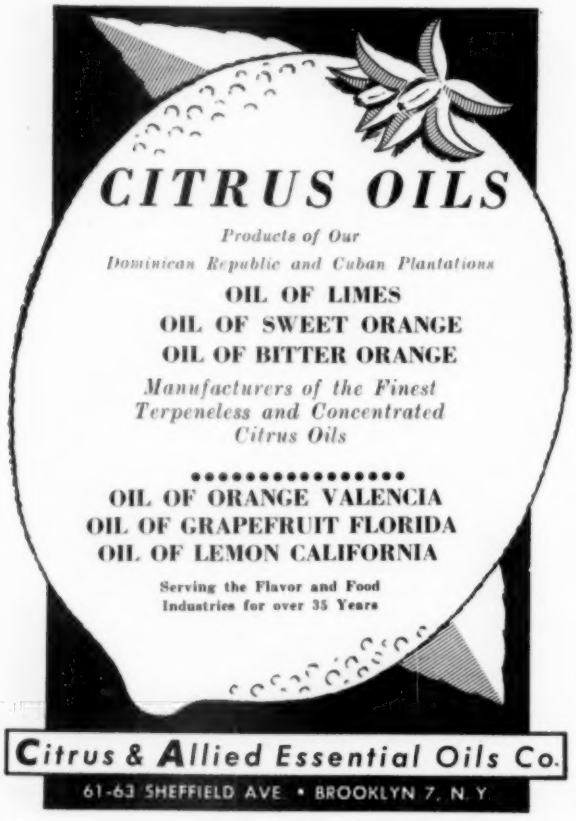
rimocidin, nystatin, fungizone, actidone, and griseofulvin. Sorbic acid required higher concentrations for complete inhibition of the test fungi than the antibiotics. (See page 124.)

Flavor improvement *Use of flavor enzymes*

Application of flavor enzymes to processed foods. I. Panel studies. Kurt S. Konigsbacher, Erie J. Hewitt, and Ralph L. Evans.

The effect of flavor enzymes on a variety of processed foods and on flavor precursor solutions has now been evaluated by a considerably larger heterogeneous group of judges which included food experts as well as non-technical people. Data obtained from a series of demonstration tests showed that the addition of flavor enzymes had a significant effect on the flavors of the test foods but that the effect of the flavor enzymes differed markedly depending on the test materials. A difference was found in 98.5% of all cases. The majority of responses (79%) also indicated a preference for the flavor of the enzyme-treated samples, while in 10% of the cases the flavor of the untreated controls was preferred. The preference ratings given for the enzyme-treated foods were broken down further into *slight, distinct, strong,* and *very strong.* A slight preference was shown in 25.3% of judgments, a distinct preference in 33.8% of judgments, a strong preference in 13.0% of judgments, and a very strong preference in 6.9% of judgments. (See page 128.)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New product *Fish flour, fish meal*

Fish flour and fish meal by azeotropic solvent processing. Ezra Levin.

The first plant producing defatted dehydrated whole fish meal solvent extraction is now operating at New Bedford, Massachusetts. Capacity is 75 tons daily. Water is distilled and oil extracted simultaneously. Solvent is ethylene dichloride. Removal of fat insures stability and helps prevent biologic deterioration of meal in storage. Biological value of protein is as high as fish from which meal is derived. Meal includes fish solubles and is richer in accessory growth factors than fish meal made by conventional method of steaming and pressing. Fish oil produced is of good quality and stable. Various types of fish flour for human use are ground and screened (80-mesh) for areas where fish flavor is desired; deodorized by prolonged steaming for areas where partial deodorization is adequate; deodorized by solvent extraction with ethyl alcohol for areas where a neutral flavor is required. Protein of these types of fish flour is shown to be of equal biological value, undiminished after one year's storage at room temperature. Defatted, dehydrated fish flour makes possible inexpensive, abundant, stable animal protein. This process for producing stable, high quality meal and oil makes possible exploitation of the sea as a source of great wealth, especially significant to underdeveloped countries needing feed, food, and exports. (See page 132.)

Freezing technology *Green snap beans in retail packages*

Time-temperature tolerance of frozen foods. XVI. Quality retention of frozen green snap beans in retail packages. W. C. Dietrich, Marvel-Dare Nutting, R. L. Olson, F. E. Lindquist, Mildred M. Boggs, G. S. Bohart, H. J. Neuman, and H. J. Morris.

Controlled experiments were carried out with commercially packed frozen beans over a −30° F. to 40° F. temperature range. Sample lots were selected to represent differences in variety, growing area, harvest year, processing conditions. Variations in blanching conditions were encountered which affected rate of deterioration. A general description of quality loss of frozen green beans is given, quantitative aspects of deterioration are discussed, and a quality index based on chlorophyll measurement is proposed. Blanching under high-temperature, short-time conditions is suggested as a means of minimizing the deterioration rate. (See page 136.)

Edible non-toxic coating *For poultry meat*

Edible protective coatings for extending the shelf-life of poultry. R. C. Meyer, A. R. Winter, and H. H. Weiser.

Cut-up chicken and eviscerated half-birds were coated with edible non-toxic coating materials. To determine the value of these coatings in retarding microbial spoilage under various storage conditions, the coating materials were employed with and without a conventional wrapper and in conjunction with various antibiotics at storage temperatures of 75°, 55° and 35° F. Samples were withdrawn from storage at given intervals and examined organoleptically and bacteriologically. The coating materials did not alter the appearance of the samples and were most effective when employed in combination with one or more of the antibiotics. (See page 146.)

IMITATION VANILLA BEAN FLAVOR BY FIRMENICH

Vanilla Bean Flavor by Firmenich stems from the vanilla bean. By original research, its components and desirable characteristics have been isolated, identified, and synthesized. By patient and painstaking laboratory techniques, they have been reconstructed for you in a precise and potent flavor material with all the aromatic qualities of the original.

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You, Your Job, Your Talents, and Success*

Milton L. Rock

Vice President Edward N. Hay & Associates, Incorporated
Philadelphia

YOUR EXECUTIVE COMMITTEE was kind enough to allow me to choose my own topic. I suspect that many of the management, sales and technical personnel here tonight feel a concern that they may not be given the proper recognition in the framework of their company and that a subject that may be a proper self-interest, as well as a corporate interest, might be of import.

Dr. M. L. Rock

In order to develop the subject that proper recognition and reward depends on performance appraisal and job counseling, I propose to explore first, "what 'makes or breaks' a job"; second, "what 'makes or breaks' a person"; "what successful people are made of"; and, lastly, "how to get the most out of your talents."

WHAT "MAKES OR BREAKS" A JOB

Every job exists for a purpose. Every job must produce some end result that makes a difference. The value of your job is not what it takes to do it, but what results from doing it. This is what we call "accountability." Accountability is different from what you do; it is rather what results from what you do. One of our clients was having a problem, serious in that breakdowns of equipment became frequent. The equipment operator maintained that he was not at fault; he was doing his job. "I am watching the gauges and adjusting the valves." After discussion with the operator, the accountability of his job was emphasized to him as "constant line pressure." His comment was, "I will take care of that." The client reports a minimum of breakdowns. Everyone of us gets up in the morning, washes, dresses, and gets to work—this is responsibility—your duties. Accountability asks, "what difference does it make for us to get up in the morning, wash, dress, etc.?"

I would like to go into the question of accountability a little deeper. Accountability can be understood better by using the following 3 factors in your thinking:

How much and what kind of guidance is received, or how much freedom to act is in the job;

What is the dollar magnitude or size of area effected; and, thirdly,

What is the impact on this area?

Keeping these 3 evaluation guideposts in mind, you can then look at your own accountability for end results in the following 7 areas of endeavor.

Your *4 Management* functions:

1. Your accountability for organization structure, staffing, and reviewing;
2. Your accountability for tactical planning for action (long and short range plans);
3. Your accountability for execution, getting the work done; and
4. Your accountability for reviewing, the basic appraisal of performance against the preceding 3 management accountabilities; and

Your *3 Survival and Growth* functions:

1. Your accountability for policy, essentially your accountability for doing something about competition within the industry, economics, business cycles, government, management creed and so on;
2. Your accountability for innovation, this is strategic planning, creativity, and dynamic research to keep abreast of tomorrow; and
3. That which is always found at the bottom right-hand corner of the balance sheet—profitability, considered only when it is related to risk taking.

I beg your indulgence in this technical discussion. This is the most important part of your understanding of your job—"makes and breaks." It is like Casey Stengel's statement that he doesn't care how many runs the opponent gets, but he wants to get the most in 9 innings. It is like learning golf; if you want to score you must have the object of accountability for end results in mind. Sometimes you will use your putter to get out of a sand trap. The goal of golf is to have the fewest strokes to the hole. The goal of your job is to make a difference to the end result of your company's survival and growth.

WHAT "MAKES OR BREAKS" A PERSON

There are 2 questions we must explore to answer this one question. Firstly, what "makes and breaks" any person for any executive, sales or professional-technical job; and, secondly, what "makes or breaks" successful people from advancing and then maintaining leadership in specific jobs.

* Presented before the Philadelphia Section of IFT, Nov. 4, 1958.

During the last 9 or 10 years we have been collecting psychological and performance information on all client executives, making an annual salary of $5,000 and upward to approximately $100,000. We have collected this information on 30 items such as intelligence, ability to communicate orally and in writing, age, experience, education, ability to take risks, quantitative reasoning, and so on. In order to give you some idea of the kind of data that comes out of investigations of this sort, I have selected for discussion one corporation in the field of oil and natural gas with a total payroll of over 3,500 for whom we had the opportunity of reviewing the top 218 men, including the chief executive and his operating committee.[b]

We found that age and salary can be used as the base requirement in which to appraise the other test information. For example, in the group under discussion the age ranged from 23 to 63 years of age; the average age, 42 years. The salary ranged from $5,000 per year to $75,000 per year; the median salary, $9,000 per year. Referring to Figure 1, the age-salary

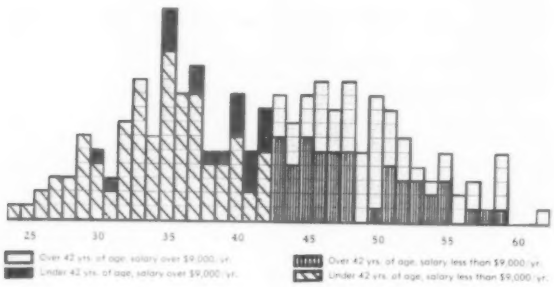


Figure 1. Age vs. salary.

chart, you will note that although age and salary do have direct correlation, there are some exceptions that must be considered and studied very carefully when you are examining executive competence. For example, there are 18 people under 42 who have a salary of $9,000 or more per year. These are the "stars" in this particular company. Salary reward is clearly at least one very important criterion.

Let us follow through these 18 people and compare them to the rest of the group. As you can see in Figure 2, executive education in this company ranges from high school not complete to postgraduate courses. There is no one under 42 who has not completed high school. The so-called "star population" falls within the high school graduate group to the postgraduate group, although more of them fall in the college and post college graduate work. This is not the same pattern as the men over 42 and having salaries of $9,000 per year. They appear to fall in all groups. Considering the population as a whole, education is not an essential factor except in the young group there seems

[b] Presented to the Thirteenth Congress of International Association of Applied Psychology, April, 1958, and published in American Management Association's *Personnel*, November, 1958 issue.

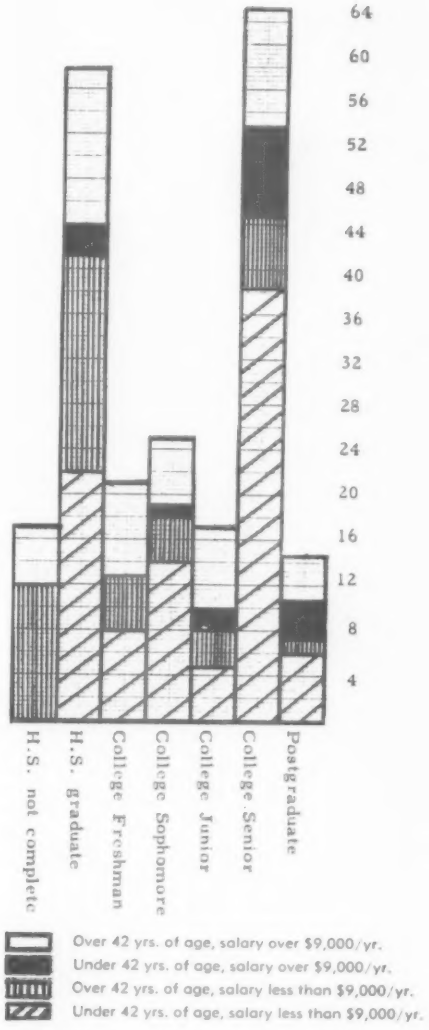


Figure 2. Education vs. salary.

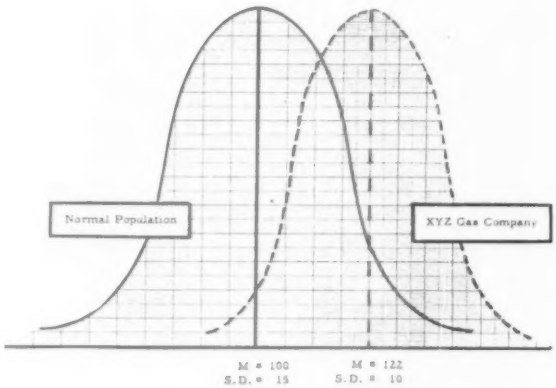
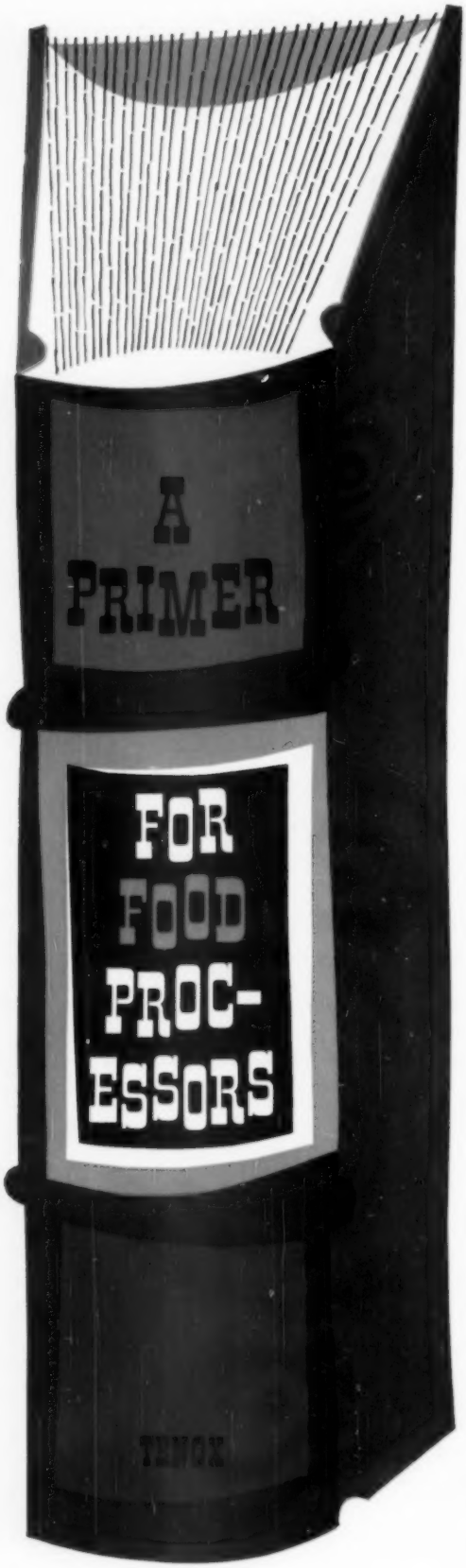


Figure 3. Intelligence: executive vs. normal population.



What you should know about oxidative deterioration

What is oxidative deterioration?

In fats and in foods containing fats, oxidative deterioration is caused by the reaction of oxygen in the air with the unsaturated portion of the fat molecule. This reaction produces free peroxide radicals which, in turn, appear to trigger a lengthy chain reaction, the result of which is the formation of a variety of aldehydes, ketones and acids. Once started, the breakdown cannot be reversed. In fact, if allowed to continue, it proceeds at an increasing rate.

Why is it important to food processors?

Oxidative deterioration, unless checked, rapidly takes its toll of fat-containing food products in the form of rancidity. Nothing destroys the reputation of a food product so quickly as the pungent, tallowy odor and flavor characteristic of rancidity.

How can you control oxidative deterioration?

Oxidative deterioration can be effectively controlled with antioxidants. Added to oxygen-sensitive fats and fat-containing food products, these chemical compounds step in to check the rancidity-producing chain reaction referred to above. Since the reaction leading to rancidity cannot be reversed, antioxidants can only prevent further deterioration. Hence, it is essential that they be added as early in the processing of the food product involved as possible.

Which antioxidant is best for you?

The principal food-approved antioxidants in use today are butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and propyl gallate. All are available from Eastman, alone or in solution formulations containing various combinations and ratios of BHA, BHT and propyl gallate, with or without a metal chelating agent.

The most effective and economical formulation for use in any given food product depends upon such factors as the food itself, how it is processed, methods of distribution and storage, and types of packaging. Advice and assistance in selecting the best formulation for your specific requirements is available from the Eastman food laboratories.

Where are these antioxidants available?

Marketed under the trade name TENOX, these food-grade antioxidants and the experienced technical service which backs up their proper use are available from Eastman Chemical Products, Inc., subsidiary of Eastman Kodak Company, Kingsport, Tennessee.

Tenox Eastman food-grade antioxidants

SALES OFFICES: Eastman Chemical Products, Inc., Kingsport, Tenn.; New York; Framingham, Mass.; Cincinnati; Cleveland; Chicago; Houston; St. Louis. **West Coast: Wilson Meyer Co.,** San Francisco; Los Angeles; Portland; Salt Lake City; Seattle; Denver; Spokane; Phoenix. **Canada: P. N. Soden Co., Ltd.,** Montreal, P.Q.; Toronto, Ontario.

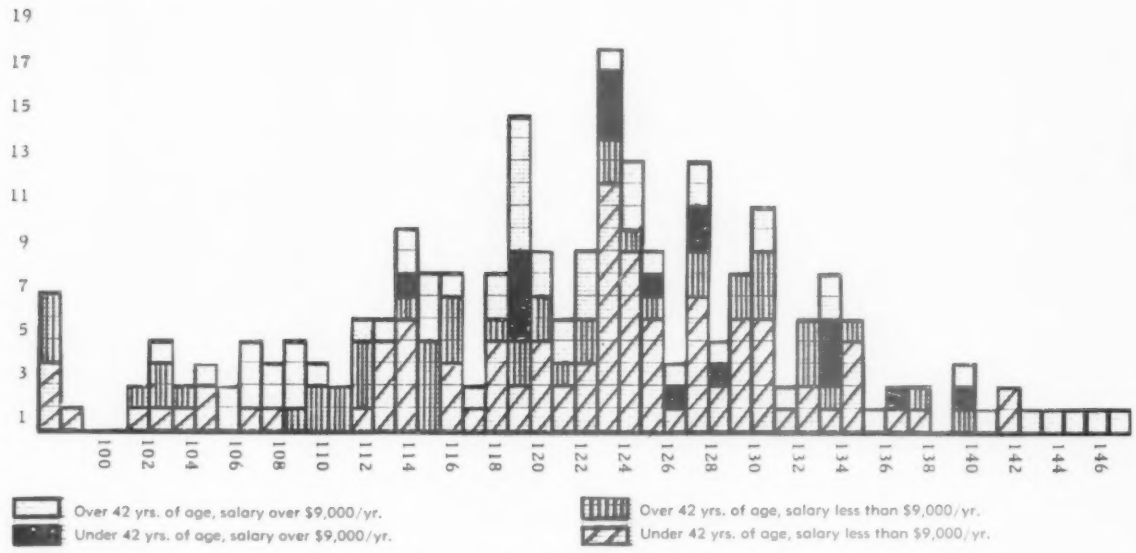


Figure 4. Intelligence vs. age and salary.

to be some advantage. Younger men, however, will reflect the present day trend toward more education for everyone.

Figures 3 and 4 illustrate intelligence as defined by the Wechsler Adult Intelligence Scale. The normal population as described by the Wechsler has a mean of 100 and a standard deviation of 15. The executive population of the XYZ Gas Company has a mean of 122 and a standard deviation of 10. Both these curves are normally distributed. It is interesting to note that the executive population curve just about starts in the mean of the normal population curve. It should also be recognized that the Armed Forces use 110 and/or 115 as a cutting off point for Officers' Candidate Schools indicating the minimum intelligence requirements for service leadership.

In Figure 4, reviewing the intelligence quotients as they relate to men, considering age and salary, we note that the young "stars," those men under 42 making $9,000 or more a year, fall above 115 I.Q. In

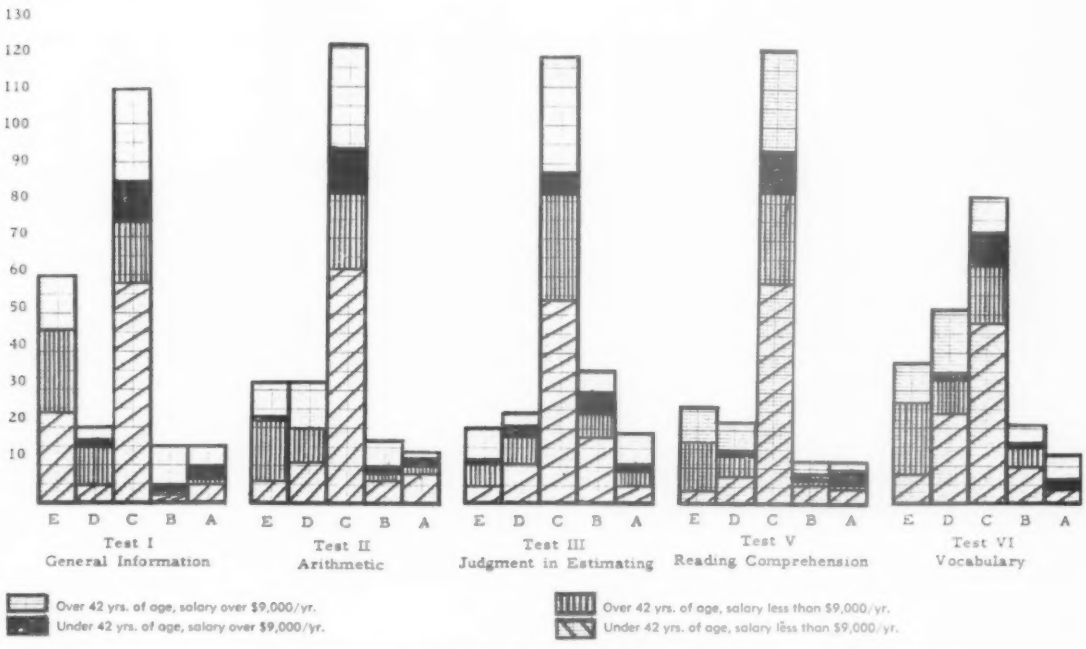


Figure 5. Aptitude vs. age and salary.

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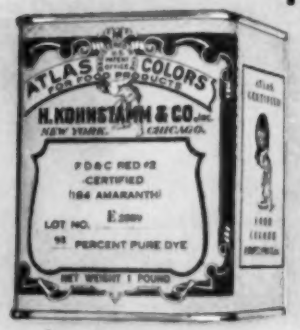

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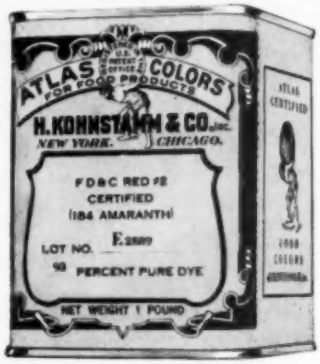

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fact, all except 1 fall at 120 or above. It should also be noted that only 15 out of 60 of the men over 40 making salaries of $9,000 fall below 115. Undoubtedly, superior intelligence is an advantage if not always a basic requirement for successful achievement in industry.

To illustrate just 1 aptitude test, we have shown on Figure 5 the XYZ Gas Company's results in 5 tests of the Cleeton Mason Vocational Aptitude Examination. The standards exhibited here are those established through our own research of 1,500 executives. They are different—more difficult than the standards of college populations. It will be noted that despite some scattered exceptions the achievement of our young "star" group, in factors found to be critical for effective executive functioning, is as good or better than the average achievement of the executive population. They are generally well informed, have good computational skills, effective basic verbal facility, and they can make sound, swift practical judgments. Primarily in the latter, do some of them need further development.

In summary, this shows what we have thought to be true a long time:

a. That executives are smarter than the general popula[illegible] more alert to their environment, and make be[illegible] use of their capabilities;

b. That age and salary seem to be related; and

c. That the young smart individuals receive financial rewards more quickly.

These and 24 others can differentiate those people who have the basic talents and abilities that "make or break" the getting the chance to try out for the team. In boxing parlays, these are the fellows that make the weight and have a natural talent to be contenders. Then comes the training and the contests with the resulting performance appraisal. This performance appraisal is based on the man's ability to produce the proper end result—his accountability to win. The man produces a record—his performance record against rated competition—and the time comes to put him in the "big time."

We now come to the second question:

WHAT "MAKES OR BREAKS" A SUCCESSFUL MAN FROM ADVANCING AND THEN MAINTAINING LEADERSHIP IN SPECIFIC JOBS

This was a tough problem for us. All the fellows that get up to the level of achievement are good—they all have "cut the mustard" in tough campaigns. We are asking, "what makes the difference between a Joe Lewis and a Max Schmelling, a General Lee and a General McClellan, the New York Yankees and the rest of the American League?" Our research in this area has demonstrated the following 5 factors that differentiate a successful executive from the unsuccessful or mediocre, remembering that the unsuccessful or mediocre are unsuccessful and mediocre only in top flight championship contests. If we were to differentiate here between cars, we might say that the performance of 2 cars is equal up to 70 miles an hour, but at speeds in excess of 70 miles an hour, one car continues to perform efficiently and effectively while the other car might shimmy, shake, and eventually break down. The 5 factors are as follows:

1. The successful executive understands and has the capacity for his own survival. He is like the cat that has 9 lives and always lands on his feet. He may lose the battles but always wins the war.
2. The successful executive has a deep conviction concerning his own ability and indeed an expectation that he can gain acceptance with anyone. He thinks more about human relations than the run-of-the-mill executive.
3. His attitude is one of a feeling of independence. He accepts himself. He is sure. He delegates, but controls. He never gives away anything.
4. He has a readiness to exert himself to the ultimate if the exertion will result in reaching the goal.
5. He is a little ham—an actor, and likes the good things of life.

HOW CAN YOU GET THE MOST OUT OF YOUR TALENTS IN YOUR COMPANY

The following 6 suggestions are not in any specific order, but all seem to be equally important:

1. Know your accountability; know how your job supports the accountability of other jobs. Know the accountabilities of the job or jobs you aspire to.
2. Know yourself. Know what abilities and skills you have.
3. Tie your natural abilities into the job accountabilities and see what risks are involved. What are the odds for you to accomplish the end results of the job that you have or the job that you aspire to. Recognize the old adage that you only get what you pay for, and you are surely going to pay in some way or another in the top jobs.
4. Set up a definite schedule of development plans for yourself. Set these up against the accountabilities of the job you have or the job to which you aspire.
5. Development is best done on-the-job, but investigate the existing outside educational facilities.
6. Rate your performance against the "makes or breaks" of your job and keep a track record.

We have found working with over 200 clients that companies that suggest this approach and people that follow this approach get mutual benefit of having the company achieve the end results for which it is set up and for the individuals to share in the rewards of the joint accomplishments.

Fast—This is how food processors with whom we do business like their vitamin A to be supplied.

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Fifty-fourth Meeting of the Food and Nutrition Board

B. E. Proctor
IFT Representative

The Food and Nutrition Board met in the NAS-NRC building, October 31-November 1, 1958, with Dr. Grace A. Goldsmith, Chairman of the Board, presiding. In addition to members and liaison representatives, the Board was host to members of the U. S. National Committee for the International Union of Nutritional Sciences and the Organizing Committee for the Fifth International Congress on Nutrition. The Congress will be held in Washington, September 1-7, 1960. Dr. C. Glen King is President of the Congress and Dr. Paul György is Chairman of the Organizing Committee.

Dr. W. H. Sebrell, Jr., Chairman of the Board's Committee on Protein Malnutrition, reported on the results of a $250,000 research program on development of protein foods in food-deficient countries. This program, with funds provided by the Rockefeller Foundation, was coordinated with international programs of UNICEF, FAO, and WHO.

The Board also previewed and approved for publication a report entitled "Evaluation of Protein Nutrition with Emphasis on Amino Acid Proportionalities," prepared by the Committee on Amino Acids under the Chairmanship of Dr. James B. Allison. This report presents a comprehensive background for critical consideration of the addition of specific amino acids to cereal foods for improvement of protein quality.

A group from the National Institute of Dental Research of the National Institutes of Health under the leadership of Dr. S. J. Kreshover prevailed upon the Board for counsel in a proposed study of dietary phosphates and dental caries to be conducted in cooperation with the Bureau of Indian Affairs, Health, Service.

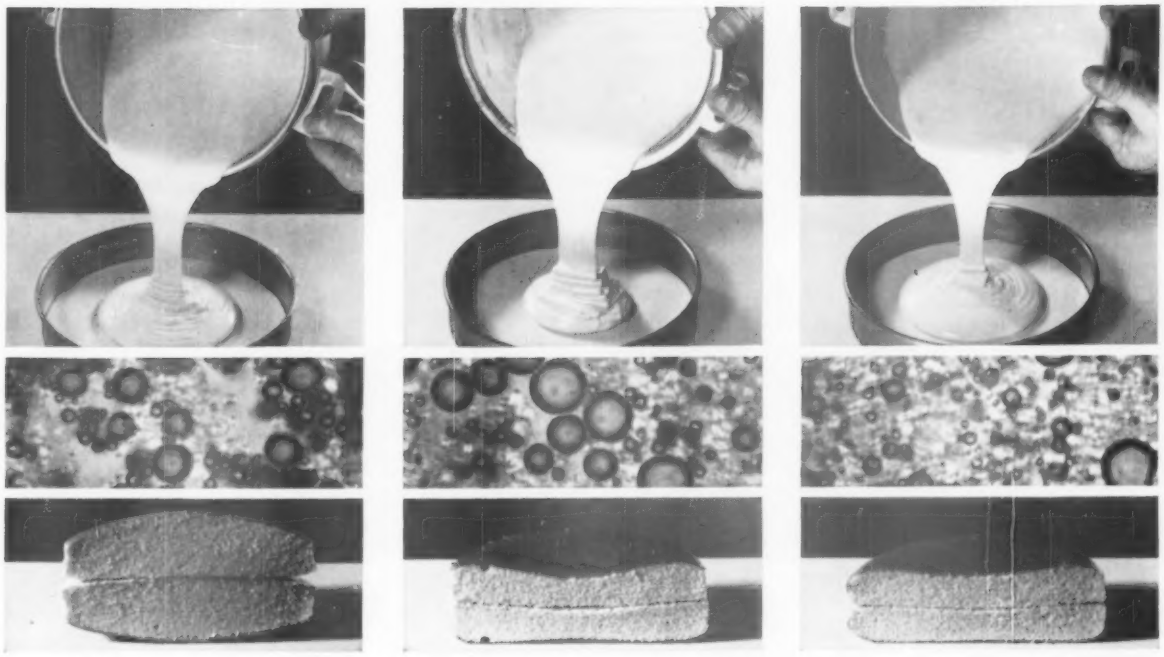
Dr. William J. Darby apprised the Board of the extensive work of the Food Protection Committee with reference to the 1958 amendment to the Federal Food Drug and Cosmetic Act. A report of the Committee entitled "Food Packaging Materials—Their Composition and Uses," was approved for publication.

A new committee of the Board has been organized under the chairmanship of Dr. Robert L. Jackson to reconcile some of the conflicts of opinion on infant nutrition.

With the publication of the 1958 Recommended Dietary Allowances, the Committee Chairman, Dr. Robert E. Shank, was released, and a new Committee on Dietary Allowances, with Dr. Wendell H. Griffith as Chairman, was nominated to look ahead to the next edition.

From liaison representatives and guests the Board was advised of:

Cake drama in three acts, starring the emulsifier



I II III

Curtain raiser Here is a rather thick but pourable batter with a very slight curdle. Below it, a peek into the live batter, one hundred times actual size, reveals a wide distribution of air bubble sizes. Not all the fat has been used up in making bubble walls. Darker areas of reserve fat are seen by the naked eye as curdle. Then, as the relatively weak-walled bubbles gently break during baking, the fat assumes its second role of coating the gluten-and-starch framework. First-act climax: a good cake. Excellent volume, fine and even grain, thin cell walls, whiteness.

Plot thickens It's the same formula otherwise, but emulsifiers have been chosen to make a very smooth, very thick batter. In the photomicrograph you see why there's no curdle: all the fat has been used in making big, thick bubble walls. You also see why the batter is so viscous: the big bubbles get in each other's way. Here, alas, the emulsifier builds *too much* strength into the bubble walls. Suspense. By the time the bubbles finally do break, considerable gas pressure has built up. The sudden release of energy shatters the still tender skeletal structure. Tragedy!

Anticlimax Now we have swung off to another extreme, using in the same formula emulsifiers that produce a very smooth and very thin batter. Note the small, uniform bubbles floating in a sea of liquid. (There's your low viscosity.) Note the fat all used up in making the bubbles strong. (No curdle.) Finale: in the oven, sudden energy release produces the same collapse as in Act II, with thick cell walls and open grain.

Program note: The offstage voice advancing hypotheses about bubble strength is that of one batter theoretician among many. He has never been inside a cake in the oven.

EPILOGUE: Texture, both of the batter and of the cake, depends on the emulsifier. With *Myverol® Distilled Monoglycerides*, the texture is subject to practical engineering control, regardless of the fine points of underlying theory. Such control is both possible and economical because we, in our own production, have the precise control that comes from segregating fats as vapors. Interested in what we can do for you with this unique power? For particulars, write ***Distillation Products Industries,*** Rochester 3, N. Y. Sales offices: New York and Chicago • W. M. Gillies, Inc., West Coast • Charles Albert Smith Limited, Montreal and Toronto.

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The work of the Interdepartmental Committee on Nutrition for National Defense by Dr. Arnold E. Schaefer; the work of the Canadian Council on Nutrition by Dr. E. W. McHenry; the work of the Council on Foods and Nutrition of the American Medical Association by Dr. Philip L. White; the work of the Institute for Scientific Research in Central Africa by Dr. Louis Van Den Berghe.

At its dinner meeting the Board was addressed on the subject, "The S in UNESCO" by Dr. Raymond L. Zwemer, Office of the Science Adviser, Department of State.

INDUSTRY NEWS

Development in research quantities of a new type of corn amylomaize, with extraordinary possibilities in the production of new types of starches with application in many industries, and of economic benefit to the nation's corn growers, was announced recently by the National Starch Products Inc., and American Maize-Products Company, co-venturers in the project. At a news conference in Chicago, the chief executive officers and research directors of the companies said that the project, in being since 1953 with Bear Hybrid Corn Company, Decatur, Illinois, and the U. S. Department of Agriculture Northern Research Laboratory, Peoria, Illinois, is a dramatic demonstration of cooperative investigation and research between private enterprise and government.

They said that new avenues of research now being explored may be regarded as a scientific break-through of economic importance to corn growers, industries which will be able to improve present products and develop new ones through the chemical processing of starch from the new type of corn, and the ultimate corn requirements and sales volumes of American Maize-Products and National Starch Products.

President Theodore Sander, Jr., and Research Director James W. Evans of American Maize, and Chairman Frank K. Greenwall and Vice President—Research C. G. Caldwell of National Starch, said that preliminary research estimates of application of application of starch manufactured from the new corn, amylomaize, indicate the following possibilities in the near future.

1. Use in water soluble transparent film wrapping material for frozen foods, meats and other edible products as an advance in "built-in-maid service." Thus the housewife will be able to cook her meals without removing the wrappings, since the amylomaize wrapping materials will dissolve in the utensils as the contents are cooked. Since the film is made from corn, it becomes completely digestible when dissolved.
2. Use as a packaging material for water-dispersible products such as detergents, dyes, insecticides and industrial chemicals as replacement for the more expensive water-soluble synthetic films now used.
3. Use in non-water-soluble types for the coating and surface treatment of paper and paper products.

Looking into the research and product crystal ball, the executives of the corn refining companies said there are other fascinating opportunities which it is believed intensive independent laboratory activity by the two companies may bring about.

Recent Events of Interest with Regard to Food Additives

FLI-FDA Food Additives Conference. About 500 representatives of food and chemical companies attended a conference held in Washington, November 24–25, under the joint sponsorship of the Food Law Institute and the Food and Drug Administration. Proposed regulations for administering the new Food Additives Amendment of 1958 were the principal topic for discussion together with reviews of several facets to the scientific problems in this field. The complete proceedings of this meeting, including both formal presentations and discussions, are to be published in a forthcoming issue of the "Food, Drug, and Cosmetic Law Journal."

Food Additives Regulations. Proposed definitions and procedural and interpretative regulations with respect to food additives have been published in the Federal Register of December 9, 1958, pages 9511–9517. Single copies of these regulations may be obtained at 15 cents per copy from the Superintendent of Documents, Washington, D. C. These regulations include a preliminary list of 118 additives regarded as safe for food use. This list is not necessarily complete and does not include flavors.

Food Protection Committe. The annual meeting of the Food Protection Committee and its liaison panels was held in Washington, December 11 and 12. The first portion of the meeting was devoted to a symposium on the food additive aspects to packaging materials. These proceedings will not be published.

At the annual business meeting, Dr. L. B. Parsons of Lever Bros. was elected chairman of the Industry Committee. Other members for the coming year include O. E. May, W. M. Cox, R. L. Hall, L. H. Burt, N. D. Embree, and E. J. Matson.

Two new reports have been prepared by the Food Protection Committee, "Food Packaging Materials—Their Composition and Uses" and "The Safety of

(Continued on page 20 following technical section)

Post Mortem Aging of Poultry Meat and its Effect on the Tenderness of the Breast Muscles[a, b]

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(Manuscript received June 21, 1958)

In an age of ever increasing automation and efficiency in the poultry processing industry one of the problems is still that of providing the consumer with poultry meat of satisfactory tenderness. When poultry is packed either in ice or at refrigerated temperatures for shipment, the tenderness problem is of little significance because meat tenderizes due to aging at these temperatures. However, when poultry meat is frozen in the processing plant, lack of tenderness due to insufficient aging may become important. That meat does not age when frozen at low temperatures is an established fact. Koonz, Darrow, and Essary *(4)* found that freezing meat during the period of rigor apparently fixed the level of tenderness present in the meat. Klose, Pool, Wiele, and de Fremery *(3)* found that frozen fryers and roasters fried without prior thawing required about 12 hours aging before freezing for optimum tenderization, and that prolonged periods of frozen storage had no appreciable tenderizing effect on inadequately aged birds.

Lowe *(5)* states that if poultry meat is placed in the oven before rigor has an opportunity to develop the resulting cooked product is much more tender than if rigor had been allowed to develop, but if rigor develops during cooking the muscles are extremely tough and the carcass of the bird is somewhat twisted and drawn. Hanson *et al. (1)* pointed out that even by placing the meat in the oven only 6 minutes after killing rigor developed during cooking.

Klose, Hanson, Pool, and Lineweaver *(2)* reported that with turkeys most tenderization takes place during the first 6 hours, less in 6 to 12 hours, and less from 12 to 24 hours after slaughter. However, the degree of tenderization in intermediate periods was found to be highly variable. Also they point out that holding at chill temperature after thawing produced tenderization as effectively as holding in slush ice after evisceration and before freezing.

The work reported in this paper was designed to establish what differences in tenderness could be produced by post-mortem aging at various temperatures, times, and aging media. Turkeys and chickens of two ages were used in the 5 experiments.

EXPERIMENTAL

Methods and procedure. The research was divided into two parts involving a total of 5 experiments. Although each experiment was different, the basic techniques and methods used were as uniform as possible throughout.

Birds were shackled by both feet and slaughtered by cutting the carotid arteries on the right side of the neck. Care was taken that the wind pipe of the bird not be cut as this would increase struggling and shock. After death the birds were immersed in 53.4° C. water for 80 seconds, then subjected to a free-style automatic picker for 60 seconds. During the picking operation cold tap water was sprayed over the carcasses. Groups of 20 chickens, or 4 turkeys, were picked at one time. Immediately after picking the birds were eviscerated. Care was taken that no major body muscles be cut. The breasts of the turkeys were removed prior to cooking without cutting the breast muscles. All the meat was cooked in a reel-type oven. The fryer chickens (10 weeks old) were roasted for 2 hours at 162.8° C., the roaster chickens (14 weeks old) for 2 hours at 168.4° C., and the turkey breasts for 3 hours at 162.8° C. All meat was roasted in aluminum pans and was covered with a one-sheet wrap of 0.0015-inch aluminum foil. After cooking the meat was allowed to cool for 20 minutes before sampling. Care was exercised to minimize dehydration. Each sample was cut from the pectoralis major muscle. The sample was cut 6.6 cm. long, 2.0 cm. wide, and ranged from .75 to 1.26 cm. thick. In all cases where trimming was necessary to obtain the maximum thickness, it was done on the inside of the muscle. All samples were cut from approximately the same position in the muscle in an attempt to eliminate variations caused by bundling and connective tissue. Samples were subjected to as little air as possible between cutting and testing and the carcass was continually covered with the aluminum foil except when cutting was being done. Samples were cut from both the right and left breast muscle, each sample being treated as one observation. Tenderness measurement was made on the Kramer shear press. Each sample was weighed to one-tenth of a gram and placed in the testing cell which had been dampened by tap water. The pressure in pounds per square inch per gram of sample required to shear the sample was the tenderness score. All data were analyzed for significance by the analysis of variance complete block design.

Part I: Effects of aging media on post-mortem tenderization.

Experiment 1. Forty-eight 14-week-old turkeys and forty-eight 14-week-old chickens were obtained from the Purdue farm. In each of two replicates 12 turkeys and 12 chickens were aged in a walk-in cooler at 3.9° C. and 90% relative humidity, using either circulated air or ozone as media. The ozone was produced by a Homozone type generator running at full capacity inside the cooler. Carcasses were placed in the cooler immediately after evisceration and were aged for 2, 5, and 8 hours. At each time interval 4 birds were removed for cooking and testing.

Experiment 2. Forty-eight 14-week-old chickens were used in this experiment. In each of two replications 12 carcasses were aged in a walk-in cooler, at 12.8° C. and 90% humidity, and 12 carcasses were aged in water at 12.8° C. for 2, 5, or 8 hours. At each time interval 4 birds were removed from each media for cooking and testing.

Part II: Temperature.

Experiment 3. In this experiment forty-eight 14-week-old chickens were divided into two replications. In each replication 12 carcasses were aged in 3.9° C. air at 90% relative humidity, and 12 carcasses were aged in 12.8° C. air (also 90% relative humidity). Four carcasses were removed after 2, 5, or 8 hours of aging for cooking and testing.

Experiment 4. Seventy-two 14-week-old chickens were used in this experiment. In each of two replications 12 carcasses were aged in 0° C. slush-ice water; 12 were aged in 12.8° C.

[a] Presented at the 18th Annual Meeting of the Institute of Food Technologists, Chicago, Ill., May 28, 1958.

[b] Journal paper No. 1295 of the Purdue Agricultural Experiment Station.

water, and 12 were aged in 22° C. water for 2, 5, or 8 hours. At each time interval four carcasses were removed from each medium for testing purposes.

Experiment 5. Two-hundred and forty 10-week-old chickens were used. In each of three replications 20 carcasses each were aged in water at 0, 7.2, 12.8, and 22.2° C. for 0, 2, 4, 6, or 8 hours. At each time interval 4 carcasses were removed from each medium for testing. The carcasses aged for 0 hours were placed in the oven immediately after evisceration.

RESULTS

Part I: Media and time.

Experiment 1. Within the limits of this experiment it was found the media (air and ozone) produced no significant difference in the tenderness of either chickens or turkeys at the 2, 5, and 8 hour intervals. There was a significant difference ($P<.05$) between the tenderness scores of turkeys and chickens at the given time intervals (figure 1). Most of the aging in chicken meat took place between 2 and 5 hours and turkey meat was less tender at 5 hours than at either 2 or 8 hours. It would seem that two factors could explain this. First, the pattern of rigor, and second, the factor of dehydration which must be considered when cooling in circulated air.

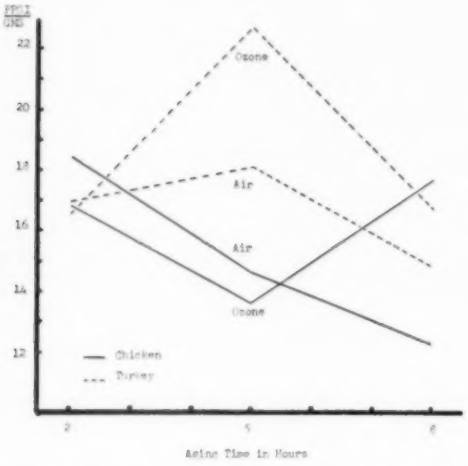

Figure 1. Graphic chart based on averages of raw data of experiment 1 in which chickens and turkeys were aged in air and ozone at 3.9° C. for 2, 5 and 8 hours and tested for tenderness.

Experiment 2. In this experiment the difference in tenderness scores between carcasses aged in water and those aged in air at 12.8° C. was found to be highly significant ($P<.01$), with the water having the greater tenderizing effect. Because of the difference in tenderness scores at 2, 5, and 8 hours, time of aging was also found to be a highly significant ($P<.01$) factor.

Part II: Temperature and time.

Experiment 3. Results of experiment 3 indicate that in explaining variations in tenderness scores after aging for 2, 5, and 8 hours at 12.8° C. and 3.9° C. in air neither time nor temperature were significant factors. However, the interaction between time and temperature is indicated to be significant ($P<.05$). In figure 3 it may be noticed that, using the 12.8° C. air as a medium, there is an appreciable decrease in the tenderness of the meat between 5 and 8 hours, which might very well be caused by either the rigor pattern or the dehydration of the meat at this temperature.

Experiment 4. Results of this experiment indicate that in explaining the variance in tenderness scores both time and temperature are highly significant ($P<.01$) factors. Data of

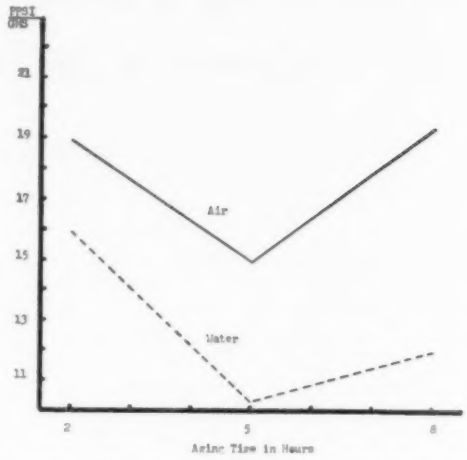

Figure 2. Graphic chart based on averages of raw data from experiment 2 in which chickens were aged in 12.8° C. air and water for 2, 5 and 8 hours and tested for tenderness.

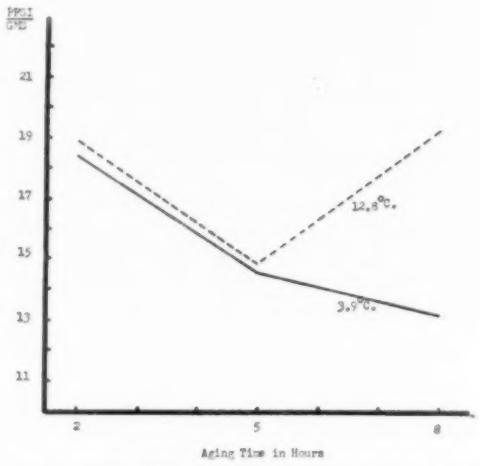

Figure 3. Graphic chart based on averages of raw data of experiment 3 in which chickens were aged for 2, 5 and 8 hours in air at 3.9° C. and 12.8° C. and tested for tenderness.

figure 4 indicate that the temperature of the aging media was quite influential in the level of tenderness at given times.

Experiment 5. In figure 5 it will be noticed that at the zero time period the variation between the highest and the lowest tenderness scores ranges over nine units. Theoretically these values should be identical, but at the zero time period any variation in time between slaughter and cooking appears to be very critical; consequently, the variation in values may simply be due to slight variations in this factor. The results indicate that both time and temperature are highly significant ($P<.01$) factors in explaining differences in the tenderness values obtained.

DISCUSSION

Results of the experiments indicate that within the limits of this study several factors may be responsible for variations in tenderness scores during the post-mortem aging of poultry meat. Time of aging, the class of poultry, temperature of aging, and the media

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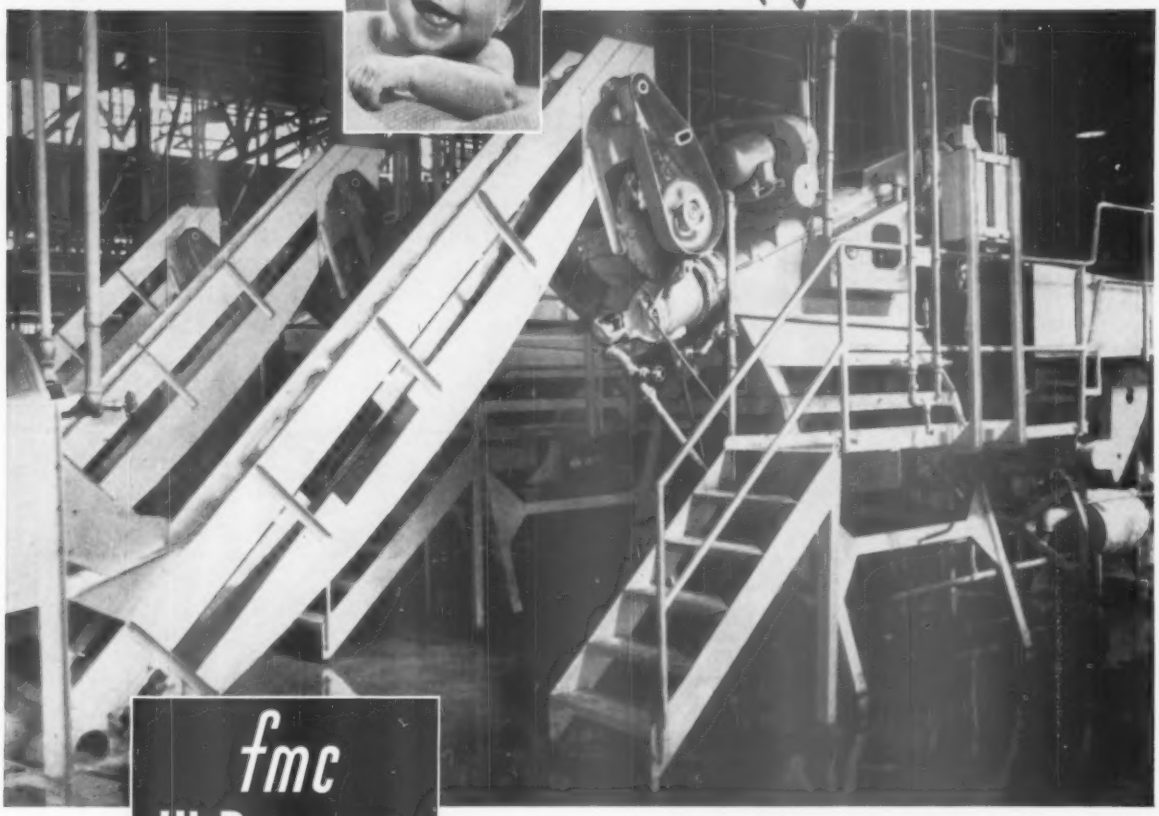

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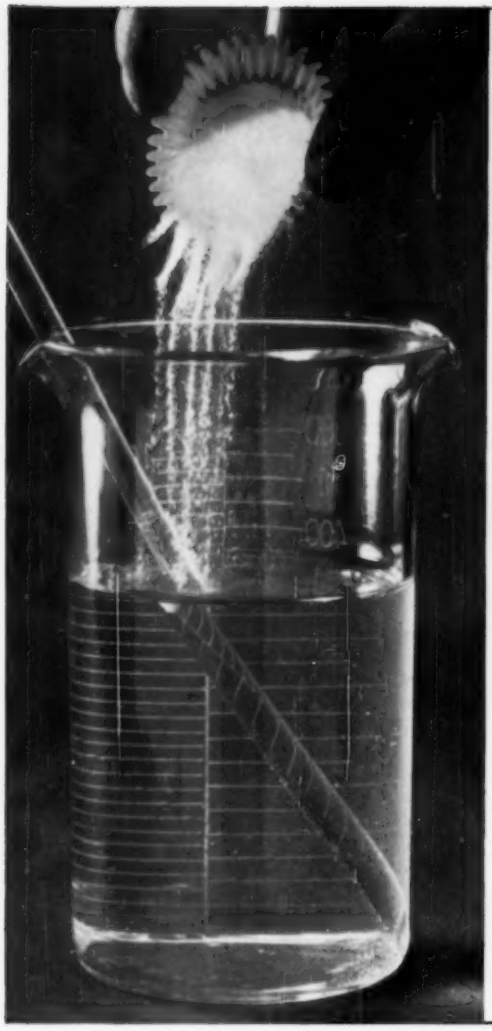

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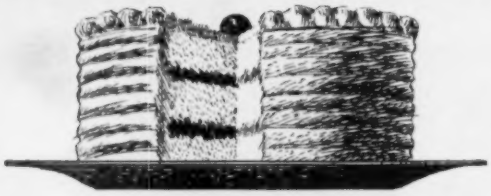

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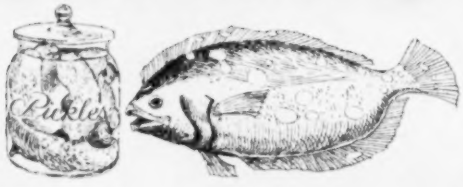

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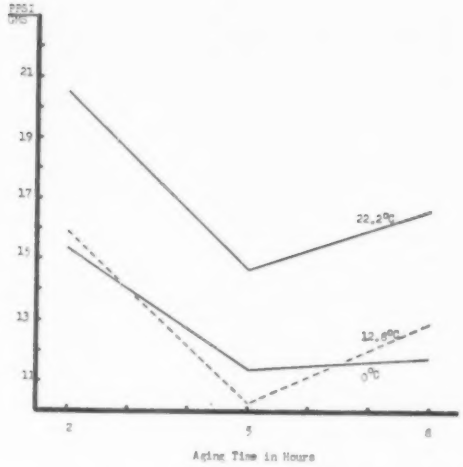

Figure 4. Graphic chart based on averages of raw data of experiment 4 in which chickens were aged in water at 0, 12.8, and 22.2° C. for 2, 5, and 8 hours before testing for tenderness.

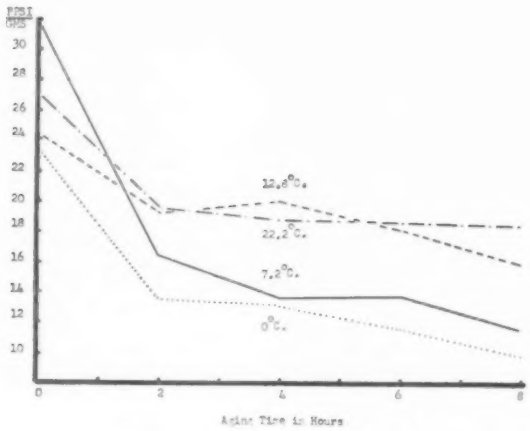

Figure 5. Graphic chart based on averages of raw data of experiment 5 in which 10-week-old chickens were aged in 0, 7.2, 12.8 and 22.2° C. water for 0, 2, 4, 6 and 8 hours before testing for tenderness.

in which the carcasses are aged are all seemingly important. The class of the birds appears to be closely related to the pattern of rigor, whereas the time of aging, and the media in which the carcasses are aged appear to be more closely associated with the actual level of these patterns. The temperature of the aging media appears to affect both the pattern of rigor and the level of tenderness at a given time, which can be observed by using water as the aging media.

It was noticed in the preliminary parts of this study when carcasses were being hung by the left wing in the walk-in cooler that even after extensive aging the left side of the breast was considerably less tender than the right side. It was felt that this was caused either by aging the meat in a relatively stretched position, or because some of the tissue fluids could have been pressed out.

The amount of water in the tissue appears to have a profound effect on the tenderness of the meat. From observations made it is felt that the effect of a lack of moisture or juiciness will be exerted on the ease with which any mechanical device will be able to shear through the meat. Further research in this area is being conducted. The time interval of the bleeding period was also observed to be influential on many occasions. If a bird was not completely bled before scalding, thus causing it to die either by shock or drowning in the scalding tank, it passed very rapidly into a rather extensive state of rigor.

Sampling, as might be expected, appears to be extremely important. The effect of dehydration on the cooked sample before testing is pronounced, as was shown in the early parts of the test when the second of two samples from any bird was found to be considerably less tender than the first sample tested. This was overcome by care in maintaining a cover of foil over the sample before testing and uniform cooling times for all samples between cooking and testing.

SUMMARY

The study, involving a total of 456 chickens and 48 turkeys, was divided into two main parts and subdivided into five experiments. The experiments were designed to measure the effects of different temperatures, media, classes of poultry, age of poultry, and time of aging on post-mortem tenderness of poultry meat.

Fourteen-week-old chickens and turkeys, and ten-week-old chickens were obtained from the Purdue Experimental Farm where they had been grown under controlled conditions. Before testing, all birds were slaughtered, picked, and eviscerated, using carefully controlled commonly accepted techniques. Carcasses were aged in air, water or high concentrations of ozone at given temperatures for designated time periods after death. After aging, the carcasses were wrapped in aluminum foil and roasted in a reel-type oven. The cooked meat was cooled for 20 minutes when uniform samples were cut from each side of the breast, weighed and tested for tenderness on the Kramer shear press.

Within the limits of this study the following results and conclusions were obtained. The age of birds slaughtered, the time of aging, the class of poultry, the temperature of aging and the media in which the carcasses were aged all appeared to be important factors in post-mortem tenderization. The class of poultry appeared to be more closely related to the actual pattern of rigor, whereas the time of aging and the medium appear to be more closely related to the level of tenderness within the rigor pattern. The temperature of the aging medium appears to affect the pattern of rigor and the level of tenderness at a given time post-mortem. Techniques in processing, sampling, and testing are very significant factors in the study of tenderness.

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Taste Thresholds for Sodium Benzoate and Sodium Sorbate in Apple Cider[a]

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Eastern Regional Research Laboratory,[b] United States Department of Agriculture, Philadelphia 18, Pennsylvania

(Manuscript received July 2, 1958)

PRESERVING FRESH FRUIT JUICES from microbial spoilage is a problem of long standing. Chemical preservatives provide the simplest method of accomplishing this purpose, but they must be used with caution because of the danger of adverse physiological effects and the problem of off-flavors. Sodium benzoate has been used for many years in preserving apple cider, and is generally accepted as a safe preservative for this purpose. It is, however, subject to the disadvantage that when added in the usual concentration (0.10%) it imparts a burning after-taste which many persons find objectionable.

Recent experiments *(1, 4)* have shown that sorbic acid and its sodium salt are useful in the preservation of cider from the action of yeasts and molds, and may be substituted for sodium benzoate in comparable amounts. Whether or not it was equally subject to objections on the basis of taste was not definitely known. Ferguson and Powrie *(1)* state only that sorbic acid in concentrations up to 0.035% could not be detected by a taste panel. It was felt that a definite comparison of the taste of sodium benzoate and sodium sorbate should be made, based on both trained panel and consumer panel methods.

EXPERIMENTAL

The cider used in these experiments was obtained from a commercial cider plant. The apples were pressed and the juice was treated with ⅕ pound of Pectinol 5B[c] per 100 gallons and allowed to stand and settle at 40° F. for 48 hours before bottling. The cider was then frozen in the bottles and kept in frozen storage until ready for use.

The sodium benzoate used was a U.S.P. grade (Baker's).[c] The sodium sorbate was prepared as a 25% solution by dissolving sorbic acid (Carbide and Carbon Chemicals Company) in sodium hydroxide solution and adjusting to pH 8.0. Since the addition of sodium benzoate or sodium sorbate to cider causes a slight increase in pH, the control samples were adjusted to the same pH by the addition of sodium hydroxide solution in order to eliminate any difference in taste due to differences in pH.

TESTS WITH TRAINED PANEL

These tests were carried out in a darkened room, illuminated only by a 25-watt red bulb. All samples were tasted at room temperature. A panel of 27 members was chosen in order to have 20 available for each test. Panel members were trained to recognize the tastes of sodium benzoate and sodium sorbate in cider, and were then given several preliminary tests at relatively high concentrations. To determine threshold levels, triangle tests were used, the comparisons being made between cider containing preservative at a given level and a control containing no preservative. Panel members were told which preservative was present but not the concentration. Each triangle consisted of one treated and two untreated samples or one untreated and two treated samples, half of the triangles being made up in each way. The tasters were asked to record the code letter of the odd sample and to state whether or not it was the one with the preservative or without. In this way, the probability of obtaining a correct answer by chance was only one in six. Twenty judgments were obtained in each test. Under these conditions, 7 correct answers are required for significance at the 5% level, and nine for significance at the 1% level *(3)*.

The threshold concentration was determined by beginning the tests at a relatively high concentration (0.10% in both

[a] Presented at the 18th Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 27, 1958.

[b] Eastern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture.

[c] Mention of trade names or products does not constitute recommendation by the U. S. Department of Agriculture over similar products not mentioned.

TABLE 1

Taste comparisons of preservative-treated cider with untreated cider. Triangle test—probability 1 in 6.

	Preservative						
	Sodium Benzoate				Sodium Sorbate		
	Concentration				Concentration		
	0.10%	0.05%	0.03%	0.02%	0.10%	0.05%	0.04%
Total number of judgments	20	20	20	20	20	20	20
Number of correct answers	18	9	7	5	15	8	5
Significance	<1%	1%	5%	a[1]	<1%	5%	a[1]

[1] Not significant.

cases), at which the difference in taste was obvious, and then reducing the concentration until the number of correct answers was not significant. Table 1 indicates that sodium benzoate was detected at 0.03%, but not at 0.02%. Sodium sorbate was detected at 0.05%, but not at 0.04%. In order to make the results more widely applicable, tests were run in a similar manner on a different sample of cider prepared later in the season and differing considerably in total solids and acidity.

Results, shown in Table 2, indicate that sodium benzoate was detected at 0.04%, but not at 0.03%, and that sodium sorbate was detected at 0.05%, but not at 0.04%. We may thus conclude that the taste threshold of the trained panel for sodium benzoate in cider was 0.04% and that of sodium sorbate 0.05%.

The next step in the experiment was to determine whether there is a detectable qualitative difference between the tastes of sodium benzoate and sodium sorbate in cider. For this purpose, a sample containing 0.04% sodium benzoate was compared with one containing 0.05% sodium sorbate, since these levels were approximately equivalent with respect to the ability of the panel to detect their presence. These samples were presented as triangles as in the previous tests. The tasters were asked to pick the odd sample and to identify it by stating which preservative it contained. Only 3 out of 20 tasters gave correct identifications, indicating that at these levels the taste of sodium sorbate cannot be distinguished qualitatively from that of sodium benzoate.

Some commercial users of sodium benzoate have stated their belief that certain brands of sodium benzoate are less easily detectable or less objectionable in cider than others. In order to test this hypothesis, samples of 6 additional brands of food-grade sodium benzoate were obtained, and each of these was compared to the brand used in the previous tests. The comparisons were made between samples containing 0.10% of each brand of sodium benzoate. In each test, the tasters were asked to pick the odd sample and to state whether it tasted better or worse than the other two. The results are shown in Table 3. Since it was required not only to choose the odd sample, but to give a preference as well, a total of 8 choices in favor of one brand or the other would be required for significance *(2)*. Inasmuch as such a preference was not shown in any of the comparisons, it may be concluded that none of the 6 additional brands tested was significantly superior or inferior in taste to the brand originally used.

TABLE 2

Taste comparisons of preservative-treated cider with untreated cider. Triangle test—probability 1 in 6.

	Preservative			
	Sodium benzoate		Sodium sorbate	
	Concentration		Concentration	
	0.04%	0.03%	0.05%	0.04%
Total number of judgments	20	20	20	20
Number of correct answers	9	6	10	5
Significance	1%	b[1]	1%	b[1]

[1] Not significant.

TABLE 3

Taste comparisons of seven brands of sodium benzoate in cider (0.1% concentration) triangle test, 20 judgments.

Brand A compared with each other brand.

Brand	B	C	D	E	F	G
No. who identified odd sample	2	3	9	6	4	8
No. who preferred taste of Brand "A"	2	0	5	3	3	1
No. who preferred taste of other brand	0	3	4	3	1	7
Significance	None	None	None	None	None	None

CONSUMER PREFERENCE TESTS

The results of tests by a trained panel in regard to preservatives in cider are of scientific interest and perhaps of some value for practical guidance. However, they do not necessarily reflect accurately the reactions of the cider-drinking public. In order to secure information of more practical usefulness, it was necessary to carry out tests of the consumer-preference type. These tests were of the paired-comparison type; 100 judgments were obtained in each test. The panel consisted of employees of the Eastern Regional Research Laboratory, and included both scientific and non-scientific personnel. Members of the trained panel were excluded from participation in the consumer-preference tests.

The tasters were given no information as to the nature or purpose of the tests. They were given the following form to fill out:

Taste sample.....first.

1. Which sample do you prefer.....?
   (If you have no preference, make a guess.)
2. Does sample.....have an objectionable off-flavor?
   Yes or No.....
3. Does sample.....have an objectionable off-flavor?
   Yes or No.....
4. Your name.....

The code letters of the two samples were reversed halfway through each test in order to eliminate the effect of code-letter bias. The order of presentation of samples was also reversed in half the cases.

In the first test, cider containing 0.10% sodium benzoate was compared with untreated cider. Of 100 tasters, 67 preferred the untreated cider and 33 preferred the cider containing benzoate. Since 61 correct judgments are required for significance at the 5% level, and 64 for significance at the 1% level *(2)*, this result indicates a preference for the untreated cider which is significant at the 1% level. The results are shown in Table 4. An objectionable off-flavor was noted in the benzoate-treated samples by 47 tasters; 4 tasters reported an off-flavor in the control.

In the second test, cider containing 0.10% sodium sorbate was compared with untreated cider. Of 100 tasters, 56 preferred the untreated cider and 44 preferred cider containing sorbate. This is not a sufficient difference for significance at the 5% level *(2)*. An objectionable off-flavor was noted in the sorbate-treated sample by 27 tasters; 15 tasters reported an off-flavor in the control.

TABLE 4

Consumer-preference panel comparisons of preservative-treated cider with untreated cider. Paired comparisons, 100 judgments.

	Control	Benzoate	Control	Sorbate
Number who preferred.....	67*	33	56†	44
Number who found off flavor in.....	4	47	15	27

* Significant at 1% level.
† Not significant.

Of 82 tasters who participated in both of the consumer-preference tests, 35 preferred the control samples to the preservative-treated samples in both cases; 21 preferred control to benzoate but preferred sorbate to control; 13 preferred benzoate to control, but preferred control to sorbate; and 13 preferred both preservative-treated sample to the controls.

No comments were solicited other than the answers to the questions on the form, but some tasters volunteered further remarks. Those who objected to the taste of the preservative noted an unpleasant after-taste or biting astringency. Those who preferred the preservative-treated samples generally stated that they had more flavor or tang, or complained that the control was too bland or tasteless. It is obvious that a minority of tasters like the taste of preservative in cider.

SUMMARY AND CONCLUSIONS

A trained taste panel was able to detect the presence of sodium benzoate in cider at a minimum concentration of 0.04%. Sodium sorbate could be detected at a concentration of 0.05%.

When compared at the minimum detectable concentrations(0.04% for benzoate and 0.05% for sorbate), there was no detectable qualitative difference between the taste of sodium benzoate and that of sodium sorbate in cider.

Of six additional brands of sodium benzoate tested, none were significantly better or worse in taste than the brand originally chosen for the tests when compared at 0.1% concentration.

A consumer-preference panel of 100 tasters showed a significant preference for untreated cider over cider containing 0.10% of sodium benzoate. There was no significant preference for untreated cider over cider containing 0.10% sodium sorbate. Almost twice as many tasters found an objectionable off-flavor in benzoate-treated cider as in sorbate-treated cider.

On the basis of these tests it would appear that sodium sorbate shows a definite advantage over sodium benzoate as a preservative in cider from the standpoint of taste when used at relatively effective concentrations.

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Properties of the Milk-Clotting Activity of Ficin[a,b]

(Manuscript received May 31, 1958)

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Milk-clotting enzymes have been found to occur in practically all varieties of tissues. Berridge *(1)*, Talce-Niedra *(11)* and Krishnamurti and Subrahmanyan *(8)* reviewed many of the sources of milk-clotting enzymes. It appears to be a general rule that all proteolytic enzymes possess the ability to clot milk under the proper conditions. As yet no exceptions to this rule have been reported.

Despite the large number of proteolytic enzymes available, rennin, obtained from the abomasum or fourth stomach of the suckling calf in a yield of 10–12 g. of commercial material per stomach, has been used almost exclusively in cheese manufacturing. The berries of *Withania coagulans*, common in India, contain enzymes capable of clotting milk and extracts of them have been used successfully in making soft and cheddar cheese *(7)*. Krishnamurti and Subrahmanyan *(8)* have reported that ficin is more versatile in its clotting action than is rennin as it will clot not only animal milk but soya milk as well. Thus, from the practical point of view, ficin could be used for the

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[b] This investigation was supported in part by a research grant (RG-5216C) from the Division of Research Grants, U. S. Public Health Service.

production of cheeses from vegetable milks on which rennin has no activity. Such a cheese would be highly acceptable in such countries as India. They found *(8)*, in cheese-making trials, that use of ficin produced cheeses comparable in quality to that of rennin.

Perhaps the main reason the other proteolytic enzymes have not been extensively investigated for their milk-clotting ability is because the protein-digesting ability of these enzymes is so strong as to carry the clotting beyond the point necessary for the production of firm cheeses. However, there are isolated cases where the milk-clotting component has been separated from the proteolytic component. Tauber and Laufer *(13)* have shown that the milk-clotting activity of the latex of *Asclepais syriaca* can be separated from the protein-splitting activity by pH adjustment and natural coagulation of the latex. Two enzymes have been crystallized from the latex of the papaya one of which, chymopapain, has twice the milk-clotting ability of the other, papain, per unit of proteolytic activity *(3, 5)*. Krishnamurti and Subrahmanyan *(9)* have found that the milk-clotting component of fig latex can be partially separated from the proteolytic component by the use of adsorbents and fractionation with ethyl alcohol.

The rapidity of the analysis and the simplicity of the method and equipment needed make the milk-clotting technique a good method for determining the activity of proteolytic preparations. Balls and Hoover *(1)* have shown that the milk-clotting method gives an accurate measure of the proteolytic activity of papain.

It was felt that an investigation of the milk-clotting properties of ficin would be of importance because of the potential importance of ficin in the production of cheeses and the usefulness of the technique for a rapid assay of the enzymatic activity. This paper presents the results of this investigation.

EXPERIMENTAL

Enzyme. A commercial preparation of ficin obtained from Merck was used throughout this investigation. The ficin was suspended in water (glass distilled water was used throughout this investigation) and allowed to stand at 0° C. overnight. It was then centrifuged at 70,000 × *g* for 20 minutes and the clear supernatant liquid removed for use and stored at 0° C. The organic matter was determined by the method of Johnson *(6)*. For activation, the enzyme was treated with cysteine prior to mixing with the substrate.

Substrate. This was prepared from Carnation Instant dry milk solids by the method of Balls and Hoover *(1)*. The final acetate buffer concentration of the substrate was 0.20 molar. The substrate concentration given throughout this paper is before dilution with 0.20 ml. of enzyme solution, unless otherwise stated. Where 0.20 ml. of enzyme solution was added to 1.0 ml. of substrate the final concentration of substrate is obtained by multiplying by 0.833.

Irradiated sorbic acid. A saturated solution of sorbic acid, obtained from Union Carbide Chemicals Company, was irradiated for 16 hours at 45° C. with a Mineralite Lamp (Ultraviolet Prod., Inc., South Pasadena, Calif.) at 2540A wavelength. The surface of the solution (100 ml. in a 250 ml. pyrex beaker) was 8 cm. below the light. A control sample was treated in a similar fashion but protected from irradiation by Kaiser aluminum foil. The concentrations of sorbic and irradiated sorbic acid were determined by the method of Melnick and Luckmann *(10)*.

Inhibition. Rate of inhibition was determined by allowing the inhibitor to react with the enzyme at pH 5.20 until there was no further change in the milk-clotting time. The time for maximum inhibition was then used in the determination of the I_{50} values (the concentration of inhibitor required to inhibit half the enzymatic activity.)

Determination of activity. The milk-clotting activity was determined by the method of Balls and Hoover *(1)* with certain modifications. The reaction was normally carried out on 1.0 ml. of substrate to which 0.20 ml. of the properly prepared enzyme solution was added very rapidly (1–2 sec.). The test tube, 15 × 150 mm., was then rotated slowly around its long axis at a 30° angle in the thermostated bath. The time was noted for the formation of particles of casein on the walls of the tube. The results can be duplicated on the same sample with a precision of 0.5 to 1% and from day to day with a precision of 2 to 3%.

RESULTS AND DISCUSSION

The first portion of this work was devoted to a study of the effect of enzyme concentration, buffer concentration, substrate concentration, pH, and other changes on the clotting time of milk.

Effect of ficin concentration on clotting time. The effect of the amount of ficin on the time of clotting is shown in Figure 1. Balls and Hoover *(1)* found that, except for small concentrations of enzyme, the time required for clotting of milk by papain was inversely proportional to the amount of enzyme present, $E = K/t$, where E is the weight of enzyme and t is the time. They found the data for the milk-clotting activity of chymotrypsin to fit this equation exactly. At low levels of papain concentration, however, the equation $E = K/t$, no longer held. By postulating that a certain part of the enzyme was removed, probably by "inhibition" by a substance in the milk, they found that the equation, $(E-e)t = K'$, where e represented the amount of enzyme removed from action by "in-

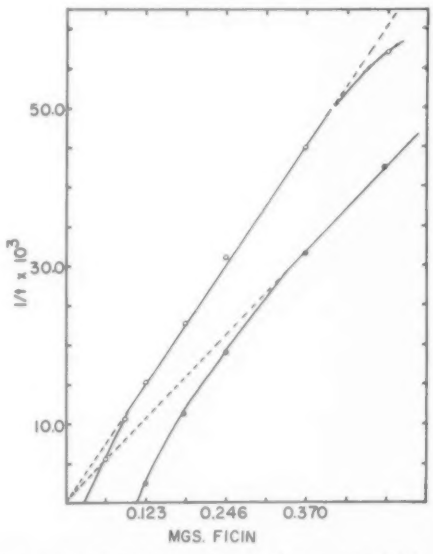

Figure 1. Effect of ficin concentration on the clotting time, t. The experiment was carried out at 35.0° C. on 1.0 ml. of 20% substrate at pH 5.20 using 0.20 ml. of enzyme activated with 1.25×10^{-2} M cysteine (○) and on unactivated enzyme (●).

hibition," correctly expressed the relation between time and enzyme concentration over the range of their experiments.

The data of Figure 1 show that the simple equation, $E = K/t$, accurately expresses the time-enzyme concentration relationship up to a clotting time of 80 seconds (0.100 mg. ficin in 0.20 ml. plus 1.0 ml. of 20% substrate) for the enzyme activated by 1.25×10^{-2} M cysteine. The final concentration of cysteine in the reaction mixture was 2.1×10^{-3} molar. In the absence of cysteine, however, the relationship is true only up to 33 seconds (0.350 mg. ficin in 0.2 ml. plus 1.0 ml. of 20% substrate). With enzyme concentrations of less than 0.100 mg. and 0.350 mg. of the ficin, in the presence and absence of cysteine, respectively, the relationship, $E = K/t$, no longer holds. It is seen from the data of Table 1 that the equation $(E-e)t = K'$ should be used to express the clotting time-concentration relationship for enzyme concentrations smaller than these. The value of e is obtained from the intercept on the x-axis of the data plotted in Figure 1. Thus, the clotting time-concentration relationship is of a diphasic nature. The deviation of the upper point in Figure 1 is explained by the clotting time, which was too short to make the time of the addition of enzyme insignificant. Shorter clotting times than 20 seconds should not be used.

TABLE 1

Amount of enzyme versus clotting time[1]

Amount of enzyme per 1.2 ml. (mg.)	Clotting time (sec.)	$E \cdot t = K$ (mg. sec.)	$(E-e)t = K'$ ($e = 0.025$ mg.) (mg. sec.)
Activated samples			
0.370	22.4	8.29	7.72
0.246	32.3	7.94	7.13
0.185	44.3	8.19	7.08
0.123	65.9	7.94	6.46
0.092	95.2	8.78	6.38
0.062	179.1	11.1	6.63
Unactivated samples			($e = 0.104$ mg.)
0.493	23.7	11.7	9.22
0.370	31.6	11.7	8.41
0.246	53.5	13.2	7.60
0.185	91.1	16.8	7.38
0.123	400	49.2	7.60

[1] The experiment was carried out at 35.0° C. on 1.0 ml. of 20% substrate buffered at pH 5.20 with 0.20 M acetate buffer using 0.20 ml. of unactivated enzyme or of enzyme activated with 1.25×10^{-2} M cysteine before addition to the substrate.

It is interesting that the amount of the enzyme that was "inactive" during the clotting process ($e = 0.025$ mg.) was approximately one-tenth the amount "inactivated" in the experiments of Balls and Hoover *(1)*. They were using 10 ml. of substrate, whereas in this experiment only one ml. was used. This tends to bear out their conclusion that the amount of enzyme "inhibited" is a property, not of the enzyme used, but of the substrate. Assuming this to be true, one would calculate a e value of 0.072 mg. for ficin in the presence of cysteine based upon the K values for ficin and activated ficin over the linear portion of the curves. Apparently, then, the difference between 0.072 mg. (calculated) and 0.025 mg. (found) is due to the effect of cysteine in preventing "inhibition" by the substrate. That cysteine can partially prevent the inhibition of the enzyme by the substrate is shown by Figure 3 and the following data: use of a substrate solution (25%) containing 1.25×10^{-2} M cysteine resulted in a clotting time of 17.3 seconds for 0.370 mg. ficin activated with 1.25×10^{-2} M cysteine while a cysteine-free substrate solution was clotted in 24.6 seconds by the same ficin solution. If the ficin is activated with sufficient cysteine to give a final concentration of 1.25×10^{-2} M when added to cysteine-free substrate, the observed clotting time was 25.8 seconds. This clearly demonstrates the presence of inhibitors in the substrate. Whether this inhibition is due to heavy metal ions or to the casein molecule is not known.

Effect of pH on the clotting time. The pH of the substrate has a tremendous effect on the clotting time as one might expect (Figure 2). The clotting time was found to decrease as the pH approached the isoelectric point of casein (pH 4.6). The reason for the exact nature of the curve is not known. It would be difficult to postulate reasons for the nature of the curve until more is known about the mechanism of the clotting process and the milk components involved. However, the data show that at pH 5.20, which is usually used for milk-clotting assays, the clotting time is extremely dependent on the pH. One must be able to control this factor exactly in order to get reproducible assays over a period of time. For this reason it may be desirable to run the assay in milk buffered at pH 6.0 where it is not nearly as sensitive to pH changes. Only about 30% sensitivity would be sacrificed by running the assay at pH 6.00 rather than 5.20.

Effect of concentration of acetate buffer on clotting time. From Table 2 it is seen that the clotting time is affected by the concentration of buffer, increasing

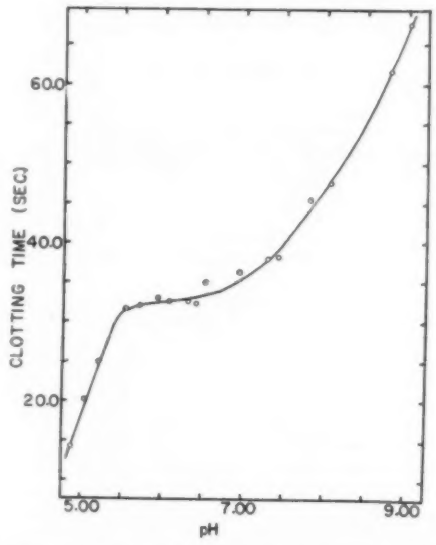

Figure 2. Effect of pH on the clotting time. Twenty per cent substrate buffered at the desired pH with 0.20 M acetate buffer was used. Cysteine-activated ficin (0.340 mg. in 0.20 ml.) was allowed to act upon 1.0 ml. of the substrate at 35.0° C. The ficin was activated with 1.25×10^{-2} M cysteine.

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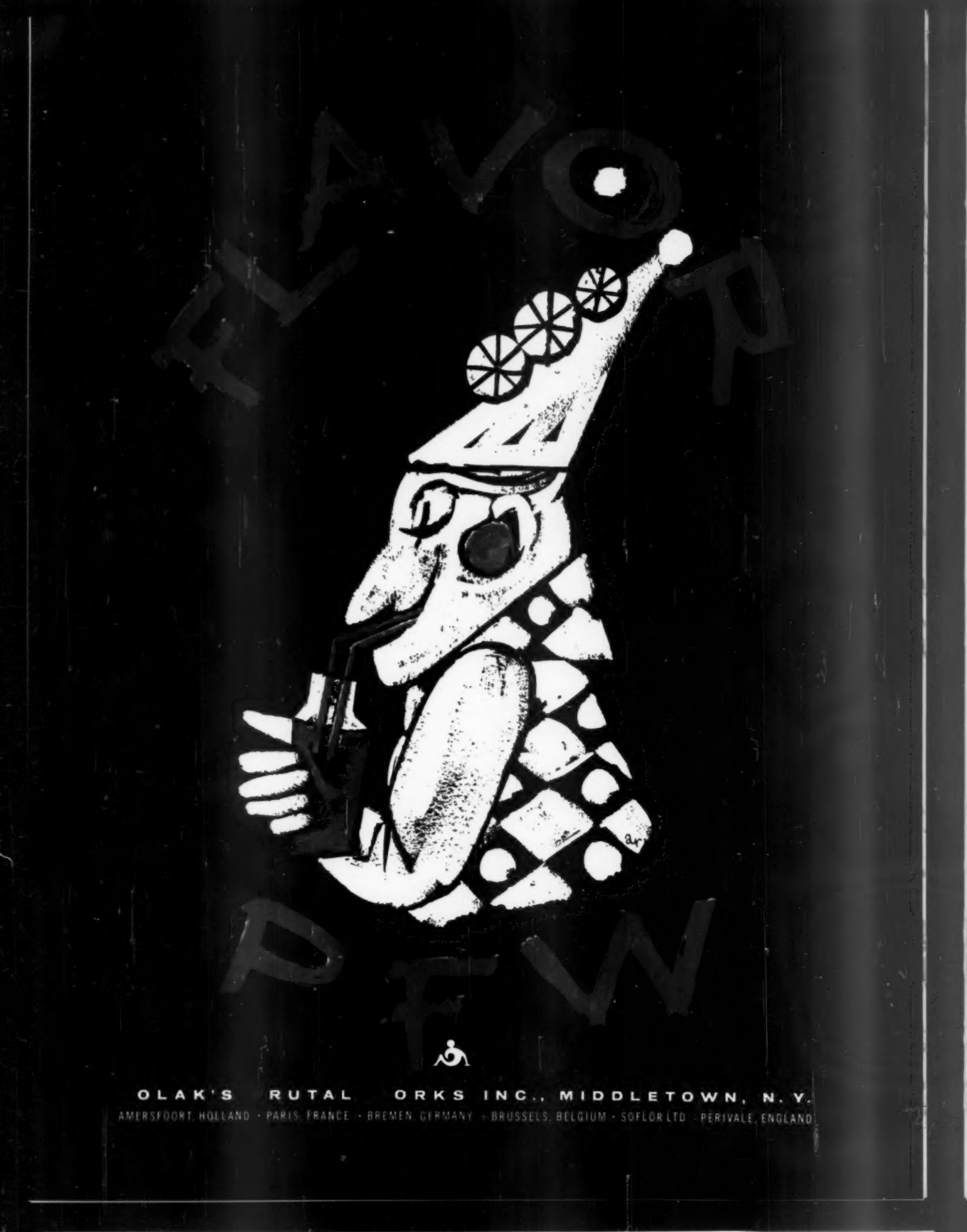
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TABLE 2

Effect of concentration of acetate buffer on clotting time[1]

Buffer concentration (molar)	Final pH	Clotting time (seconds)
None	5.40	21.4
3.35×10^{-2}	5.40	23.6
6.70×10^{-2}	5.40	24.4
1.34×10^{-1}	5.40	26.9
2.01×10^{-1}	5.40	32.1
2.68×10^{-1}	5.40	32.5

[1] Cysteine-activated ficin (0.242 mg. in 0.20 ml.) was allowed to act upon 1.0 ml. of 20% substrate buffered with various concentrations of acetate buffer at 35.0° C. and pH 5.40. The ficin was activated with 1.25×10^{-2} M cysteine before addition to the substrate.

with increasing concentrations of buffer. For example, there is a change of 52% in the clotting time on the addition of 0.268 molar acetate buffer.

Effect of volume of substrate on the clotting time. Various volumes of substrate have been used by different workers in the milk-clotting method. Balls and Hoover *(1)* used 10 ml., Balls and Lineweaver *(3)* used 5 ml., Krishnamurti and Subrahmanyan *(8)* used 2 ml. and this investigator has used one ml. Each group of investigators has defined a unit of enzyme activity as the amount that would clot the number of ml. of substrate they used in one minute at a given temperature. This makes a comparison of the results difficult if not impossible. The effect of the volume of substrate used on the clotting time is shown in Figure 3. The clotting time was found to be almost directly proportional to the volume of substrate used. If the data were corrected for the amount of enzyme "inactivated" by the substrate, by a series of experiments similar to that shown in Figure 1, it is believed that the relationship between clotting time and volume of substrate would be a linear one. In fact, it is linear over a part of the curve. Figure 3 also shows that the relationship between clotting time and volume of substrate can be improved by the use of cysteine in the substrate solution to prevent "inhibition" of the enzyme. Even the large amount used here did not completely prevent inhibition, however.

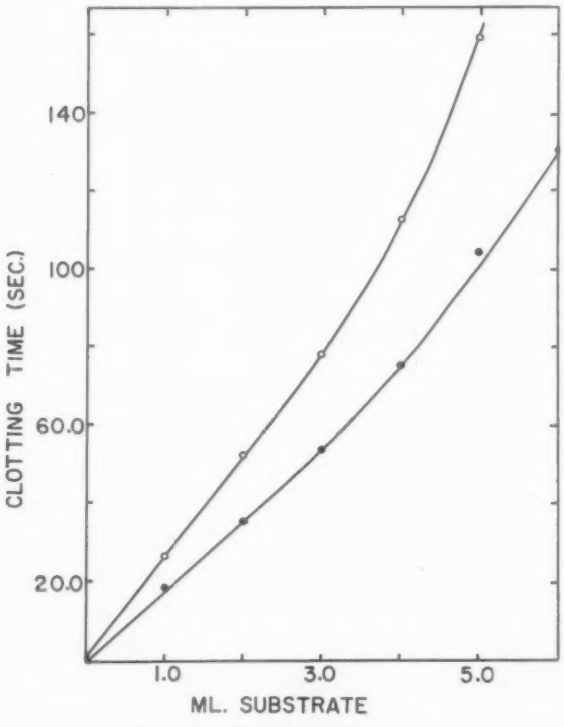

Figure 3. Effect of substrate volume on the clotting time. Cysteine-activated ficin (0.370 mg. in 0.20 ml.) was allowed to act at 35.0° C. upon various amounts of 20% substrate (final concentration) buffered at pH 5.20 with 0.20 M acetate buffer. The ficin was activated with 1.25×10^{-2} M cysteine before addition to the cysteine-free substrate (○) and to the substrate containing 1.25×10^{-2} M cysteine (●).

Effect of substrate concentration on clotting time. It is seen from Figure 4 that the clotting time is directly proportional (slope = 2.1 sec./ per cent substrate and intercept = 13.1 sec.) to substrate concentration over the range of 4 to 20% milk, deviating from linearity only at the 2% substrate level. The clotting process is very readily detected at the 8% substrate level but it requires a little more practice to be able to detect the time of clotting, particularly at the 2% substrate level.

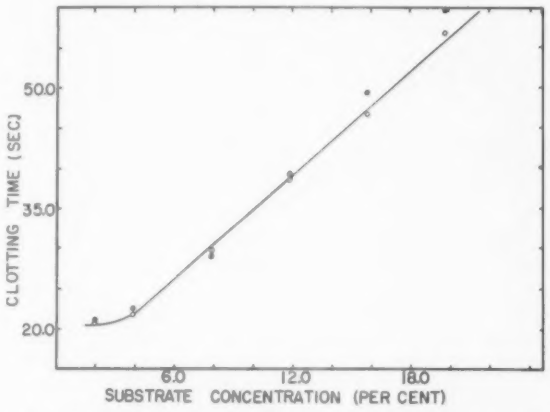

Figure 4. Effect of substrate concentration on the clotting time. Cysteine-activated ficin (0.145 mg. in 0.20 ml.) was allowed to act at 35.0° C. on one ml. of various concentrations of substrate containing 2.5 mg. $CaCl_2 \cdot 2H_2O$ per ml. (○) or substrate containing no added calcium ions (●) and buffered at pH 5.20 with 0.20 M acetate buffer. The ficin was activated with 1.25×10^{-2} M cysteine. Note that the concentrations of substrate given are initial concentrations. The initial concentration multiplied by 0.833 gives final concentration.

It was also found (Figure 4, Table 5) that adding calcium ions did not increase the time of clotting as has been reported by Krishnamurti and Subrahmanyan for ficin *(8)* and by Berridge for rennin *(4)*. However, the powdered milk substrate (20%) contained 2.5 mg. of calcium ions per ml. and even at the 4% substrate level contained sufficient calcium ions (0.50 mg./ml.) to give maximum activation according to the data of Krishnamurti and Subrahmanyan *(8)*. Therefore, no conclusions as to effect of calcium ions on the time of clotting can be drawn from the data in which powdered milk was used.

Effect of age of substrate on clotting time. Time of standing, or aging, of the substrate at room temperature had no effect on time of clotting (Table 3). However, standing at 35.0° C. in a water bath, as well as storage at 4° C., did affect the clotting time of milk. Thus, it would appear to be preferable to prepare the substrate fresh each day and to allow it to remain in the water bath for a standard period of time for temperature equilibration before addition of the enzyme. These precautions were observed in the experiments reported in this paper.

TABLE 3

Effect of age of substrate on time of clotting by ficin[1]

Aged at 35.0° C.		Aged at 22.8° C.		Aged at 4° C.	
Aging time (minutes)	Clotting time (seconds)	Aging time (hours)	Clotting time (seconds)	Aging time (days)	Clotting time (seconds)
0	33.7	0	33.7	0	33.7
10	34.8	1.5	33.2	1	31.3
20	35.2	2.0	34.4	2	26.5
40	34.8	3.0	33.7		
60	36.4	4.0	34.0		
90	37.5	7.0	34.4		
120	37.8	24	34.2		
		48	33.1		

[1] The substrate was 20% dry milk solids buffered at pH 5.20 with 0.20 M acetate buffer. Cysteine-activated ficin (0.246 mg. in 0.20 ml.) was allowed to act upon 1.0 ml. of substrate at 35.0° C.

Effect of temperature on clotting time. Evaluation of the data in Figure 5 by the method of least squares gave the following energies of activation for the clotting of milk, 15,900 calories between 30.1 and 60.2° C., 23,900 calories between 10.7 and 30.1° C. and 26,700 calories between 2.52 and 10.7° C. The reason for the change in activation energy is not known. Balls and Lineweaver *(2)* reported that papain and chymotrypsin clotted milk even at −1° C. but the time of clotting was much longer than that calculated from the activation energy determined at 30° C. Berridge *(4)* reported that rennin did not produce a clot at low temperatures. Tappel, Miyada, Sterling and Maier *(12)* also found a change in the activation energy below 30° C. although they did not make particular note of this. The value of 15,900 calories found for the activation energy for the clotting of milk by ficin (30–60° C.) is in excellent agreement with the 16,000 calories found for the action of papain on milk *(12)*.

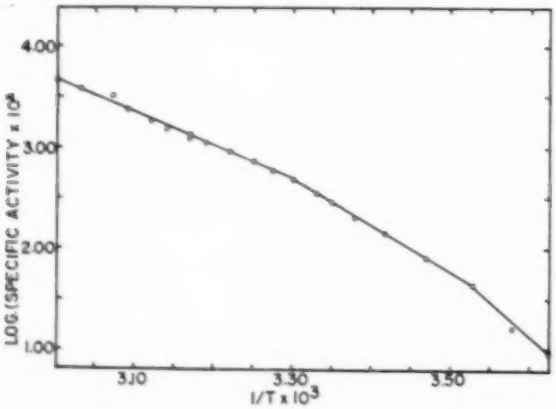

Figure 5. Effect of temperature on the clotting time. The experiment was carried out using 0.20 ml. cysteine-activated ficin and 1.0 ml. of 20% substrate buffered at pH 5.20 with 0.20 M acetate buffer. The specific activity is units of enzyme activity per mg. of ficin where one unit of activity is that amount of activity which will clot one ml. of substrate in 60 sec. at 35.0° C.

Stability of the milk-clotting component of ficin. The stability of ficin, at a concentration of 1.21 mg. per ml., pH 7.0 and 35.0° C., in the presence and absence of cysteine is shown in Figure 6. It is seen that the enzyme loses activity much more rapidly in the absence of cysteine. However, most of this loss in activity can be restored by the addition of cysteine. This would indicate that the activity lost was largely due to the oxidation of the sulfhydryl group to a disulfide group (reversible inactivation) rather than denaturation of the enzyme itself (irreversible inactivation). Therefore, this finding is in agreement with previous work *(14)* which showed that ficin lost proteolytic activity at the same rate in the presence or absence of cysteine.

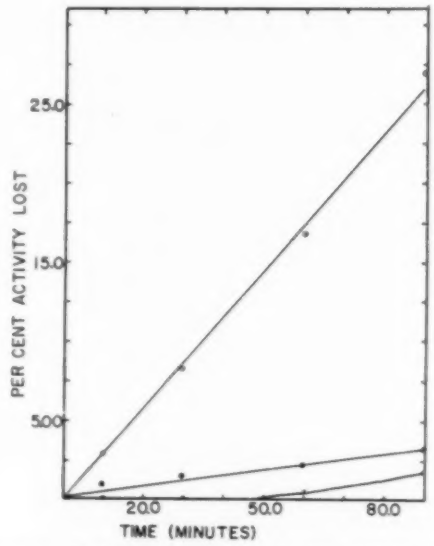

Figure 6. Stability of the milk-clotting activity of ficin. The ficin, at a concentration of 1.21 mg. per ml., was held at 35.0° C. in the presence (×) or absence of 1.25×10^{-2} M cysteine (○) or (●). The ficin was activated with 1.25×10^{-2} molar cysteine after the holding period in the experiment marked by the solid dot (●). The milk-clotting activity was then determined in the usual fashion.

Effect of activators and inhibitors on clotting time. Results of the activation-inhibition studies are given in Tables 4 and 5. The same reagents are found to activate and inhibit both the milk-clotting component and the proteolytic component *(14)* of ficin. Therefore, the milk-clotting activity is dependent upon the presence of a sulfhydryl group. These data do not give any indication as to whether the milk-clotting and proteolytic activity are dependent upon the same or different enzymes.

TABLE 4
Inhibition of the milk-clotting activity of ficin[1]

Inhibitor	Reaction with inhibitor (minutes)	I_{50} (molar)	Reactivation with cysteine	
			Inactivation (per cent)	Reactivation (per cent)
Potassium ferricyanide	10	2.0×10^{-2}	43.8	None
Hydrogen peroxide	10	1×10^{-4}	48.4	74
Sodium nitrite	5	1×10^{-2}	85.5	72
Silver nitrate	5	1.8×10^{-4}	72.5	100
Cupric sulfate	5	1.8×10^{-6}	58.4	100
Iodoacetic acid	10	5.0×10^{-6}	49.5	54
Phenylhydrazine	10	2.1×10^{-5}	48.4	60
Maleic acid	60	2.5×10^{-2}	30.0	None
Sorbic acid	10	2.8×10^{-3}	28.0	67.5
Sorbic acid	10	2.8×10^{-3}	65.0	49.7
Sorbic acid	60	4.9×10^{-4}	30.8	None
Irradiated sorbic acid	60	3.0×10^{-4}	49.8	11.2

[1] The inhibition was carried out at pH 5.20, 35.0° C. and a ficin concentration of 1.23 mg. per ml. for the specified period. The milk-clotting activity of 0.246 mg. of the inhibited ficin in 0.20 ml. was then measured in the usual way. For reactivation, the inhibited ficin was treated with 1.25×10^{-2} M cysteine for 5 min. at 35° C.

TABLE 5
Activation of the milk-clotting activity of ficin[1]

Activator	A_{50} (molar)	Maximum increase in activity (per cent)	Maximum concentration tested when A_{50} is not calculated (molar)
Cysteine	1×10^{-5}	68	.....
Sodium bisulfite	1×10^{-5}	68	.....
Sodium hydrosulfite	6×10^{-6}	57	.....
Versene	.....	17	2.5×10^{-2}
Ascorbic acid	.....	None	9.6×10^{-2}
Calcium chloride	.....	None	1.65×10^{-2}

[1] The activation was carried out at pH 5.20 and 35.0° C. for 5 minutes on 1.23 mg. per ml. of ficin. The milk-clotting activity was then measured in the usual way. The A_{50} value is the concentration of activator needed to activate half of the enzyme under the conditions used here.

Inhibitors used in this experiment can be divided into 3 groups depending upon their action on the sulfhydryl group of the enzyme. Potassium ferricyanide, sodium nitrite, and hydrogen peroxide are oxidizing agents of the sulfhydryl group and the action of these reagents can usually be reversed by the addition of cysteine. This was not found to be true particularly for potassium ferricyanide. Apparently, it carried the oxidation beyond the disulfide stage. Iodoacetic acid and phenylhydrazine are alkylating agents of sulfhydryl groups. The inhibition could be partially reversed by the addition of cysteine. It is usually true that inhibition by iodoacetic acid cannot be reversed. This was found to be true in the studies on the proteolytic activity of ficin *(14)*. Perhaps a longer reaction time or larger concentrations of iodoacetic acid would not result in a reversal of the inhibition. It is surprising to find that phenylhydrazine inhibits the clotting action of ficin since Balls and Hoover *(1)* found that it activated the clotting action of papain. Heavy metal ions, silver and copper, maleic acid and the sorbic acids inactivate sulfhydryl enzymes by mercaptide formation. Inhibition by the silver and copper ions can be completely reversed by cysteine whereas the inhibition by the other reagents is incompletely reversed, if at all. The ability to reactivate ficin which had been inhibited by sorbic acid was found to be more a function of the time of inhibition rather than of inhibitor concentration and degree of inhibition. Irradiated sorbic acid was found to be a better inhibitor of ficin than was sorbic acid. A proposed mechanism of inhibition of sulfhydryl enzymes by sorbic acid has been presented in a previous publication *(15)*.

The I_{50} values, the concentration of inhibitor needed to produce 50% inhibition of ficin, are also shown in Table 4. Such data permit a direct comparison of the effectiveness of the various inhibitors.

The milk-clotting activity of ficin was activated by cysteine, sodium bisulfite, sodium hydrosulfite and versene (Table 5). The first three are about equally effective. It should be recalled that sodium hydrosulfite gives rise to 2 molecules of sulfurous acid on reaction with water which explains its greater effectiveness on a molar basis. While versene produced about a four-fold increase in the proteolytic activity of ficin *(14)* only a 17% increase in milk-clotting activity was found. The reason for this is the use of glass-distilled water in these experiments. This indicates that the function of versene in the activation of ficin is the removal of inhibitory metal ions. Ascorbic acid was again found to be ineffective as an activating agent for ficin *(14)*.

SUMMARY

It is necessary to use both the equations, $K = Et$ and $K' = (E-c)t$, where E is the enzyme concentration, t is the clotting time, c is the amount of enzyme inhibited and K is a proportionality constant, to express the relationship between clotting time and ficin concentration over the range studied.

The clotting time for the action of ficin on milk was found to be influenced by the enzyme concentration, pH, volume of substrate, substrate concentration, age of substrate, and temperature.

The milk-clotting activity of ficin is inhibited and activated by the same reagents which inhibit and activate the proteolytic activity. The milk-clotting activity is dependent upon a free sulfhydryl group in the enzyme.

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1. Balls, A. K., and Hoover, S. R. The milk-clotting action of papain. *J. Biol. Chem.*, 121, 737 (1937).
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Effect of age of substrate on clotting time. Time of standing, or aging, of the substrate at room temperature had no effect on time of clotting (Table 3). However, standing at 35.0° C. in a water bath, as well as storage at 4° C., did affect the clotting time of milk. Thus, it would appear to be preferable to prepare the substrate fresh each day and to allow it to remain in the water bath for a standard period of time for temperature equilibration before addition of the enzyme. These precautions were observed in the experiments reported in this paper.

TABLE 3

Effect of age of substrate on time of clotting by ficin[1]

Aged at 35.0° C.		Aged at 22.8° C.		Aged at 4° C.	
Aging time (minutes)	Clotting time (seconds)	Aging time (hours)	Clotting time (seconds)	Aging time (days)	Clotting time (seconds)
0	33.7	0	33.7	0	33.7
10	34.8	1.5	33.2	1	31.3
20	35.2	2.0	34.4	2	26.5
40	34.8	3.0	33.7		
60	36.4	4.0	34.0		
90	37.5	7.0	34.4		
120	37.8	24	34.2		
		48	33.1		

[1] The substrate was 20% dry milk solids buffered at pH 5.20 with 0.20 M acetate buffer. Cysteine-activated ficin (0.246 mg. in 0.20 ml.) was allowed to act upon 1.0 ml. of substrate at 35.0° C.

Effect of temperature on clotting time. Evaluation of the data in Figure 5 by the method of least squares gave the following energies of activation for the clotting of milk, 15,900 calories between 30.1 and 60.2° C., 23,900 calories between 10.7 and 30.1° C. and 26,700 calories between 2.52 and 10.7° C. The reason for the change in activation energy is not known. Balls and Lineweaver *(2)* reported that papain and chymotrypsin clotted milk even at −1° C. but the time of clotting was much longer than that calculated from the activation energy determined at 30° C. Berridge *(4)* reported that rennin did not produce a clot at low temperatures. Tappel, Miyada, Sterling and Maier *(12)* also found a change in the activation energy below 30° C. although they did not make particular note of this. The value of 15,900 calories found for the activation energy for the clotting of milk by ficin (30–60° C.) is in excellent agreement with the 16,000 calories found for the action of papain on milk *(12)*.

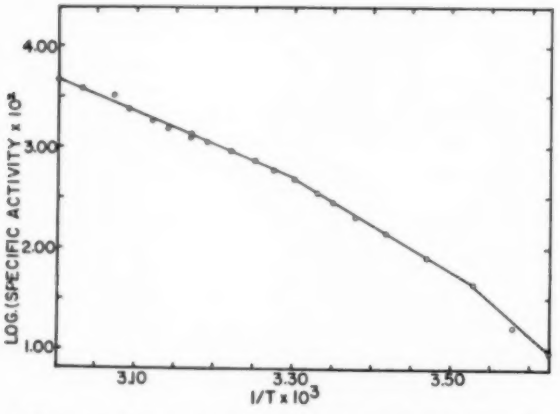

Figure 5. Effect of temperature on the clotting time. The experiment was carried out using 0.20 ml. cysteine-activated ficin and 1.0 ml. of 20% substrate buffered at pH 5.20 with 0.20 M acetate buffer. The specific activity is units of enzyme activity per mg. of ficin where one unit of activity is that amount of activity which will clot one ml. of substrate in 60 sec. at 35.0° C.

Stability of the milk-clotting component of ficin. The stability of ficin, at a concentration of 1.21 mg. per ml., pH 7.0 and 35.0° C., in the presence and absence of cysteine is shown in Figure 6. It is seen that the enzyme loses activity much more rapidly in the absence of cysteine. However, most of this loss in activity can be restored by the addition of cysteine. This would indicate that the activity lost was largely due to the oxidation of the sulfhydryl group to a disulfide group (reversible inactivation) rather than denaturation of the enzyme itself (irreversible inactivation). Therefore, this finding is in agreement with previous work *(14)* which showed that ficin lost proteolytic activity at the same rate in the presence or absence of cysteine.

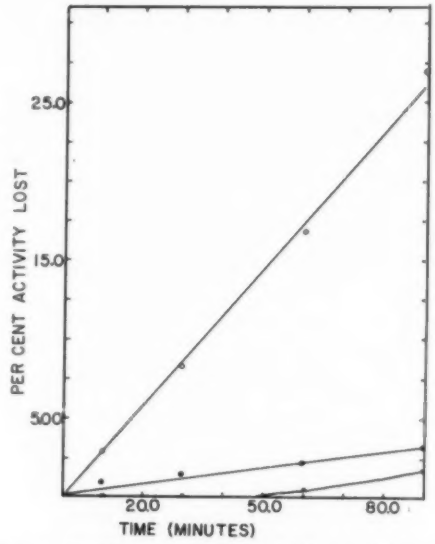

Figure 6. Stability of the milk-clotting activity of ficin. The ficin, at a concentration of 1.21 mg. per ml., was held at 35.0° C. in the presence (×) or absence of 1.25×10^{-2} M cysteine (○) or (●). The ficin was activated with 1.25×10^{-2} molar cysteine after the holding period in the experiment marked by the solid dot (●). The milk-clotting activity was then determined in the usual fashion.

Effect of activators and inhibitors on clotting time. Results of the activation-inhibition studies are given in Tables 4 and 5. The same reagents are found to activate and inhibit both the milk-clotting component and the proteolytic component *(14)* of ficin. Therefore, the milk-clotting activity is dependent upon the presence of a sulfhydryl group. These data do not give any indication as to whether the milk-clotting and proteolytic activity are dependent upon the same or different enzymes.

TABLE 4
Inhibition of the milk-clotting activity of ficin[1]

Inhibitor	Reaction with inhibitor (minutes)	I_{50} (molar)	Reactivation with cysteine	
			Inactivation (per cent)	Reactivation (per cent)
Potassium ferricyanide	10	2.0×10^{-2}	43.8	None
Hydrogen peroxide	10	1×10^{-4}	48.4	74
Sodium nitrite	5	1×10^{-2}	85.5	72
Silver nitrate	5	1.8×10^{-4}	72.5	100
Cupric sulfate	5	1.8×10^{-6}	58.4	100
Iodoacetic acid	10	5.0×10^{-6}	49.5	54
Phenylhydrazine	10	2.1×10^{-5}	48.4	60
Maleic acid	60	2.5×10^{-2}	30.0	None
Sorbic acid	10	2.8×10^{-3}	28.0	67.5
Sorbic acid	10	2.8×10^{-3}	65.0	49.7
Sorbic acid	60	4.9×10^{-4}	30.8	None
Irradiated sorbic acid	60	3.0×10^{-4}	49.8	11.2

[1] The inhibition was carried out at pH 5.20, 35.0° C. and a ficin concentration of 1.23 mg. per ml. for the specified period. The milk-clotting activity of 0.246 mg. of the inhibited ficin in 0.20 ml. was then measured in the usual way. For reactivation, the inhibited ficin was treated with 1.25×10^{-2} M cysteine for 5 min. at 35° C.

TABLE 5
Activation of the milk-clotting activity of ficin[1]

Activator	A_{50} (molar)	Maximum increase in activity (per cent)	Maximum concentration tested when A_{50} is not calculated (molar)
Cysteine	1×10^{-5}	68	.....
Sodium bisulfite	1×10^{-5}	68	.....
Sodium hydrosulfite	6×10^{-6}	57	.....
Versene	.....	17	2.5×10^{-2}
Ascorbic acid	.....	None	9.6×10^{-2}
Calcium chloride	.....	None	1.65×10^{-2}

[1] The activation was carried out at pH 5.20 and 35.0° C. for 5 minutes on 1.23 mg. per ml. of ficin. The milk-clotting activity was then measured in the usual way. The A_{50} value is the concentration of activator needed to activate half of the enzyme under the conditions used here.

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Formation of Pyrrolidonecarboxylic Acid During the Production of Beet Puree[a,b]

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(Manuscript received May 31, 1958)

IT HAS RECENTLY been demonstrated that an off-flavor in beet puree, variously described as bitter, medicinal or phenolic, is partially due to high concentrations of pyrrolidonecarboxylic acid (PCA) *(6)*. This off-flavor is not present in raw beets, but develops during processing. The immediate precursor to PCA in processed or stored foods is the amide glutamine *(2, 3, 5, 6)*, and the degradation is heat induced with the formation of PCA and free ammonia, or ammonium pyrrolidonecarboxylate, depending upon the pH.

Data were needed to provide a basis for adequate control measures in preventing the occurrence of this off-flavor and the present report concerns the effects of variations in the glutamine content of raw beets and the times and temperatures at which comminuted beets are held before retorting.

EXPERIMENTAL

Standard method of manufacturing beet puree. Beet puree was prepared on a pilot plant scale by abrasion peeling and trimming the raw beets before they were comminuted in a Fitzmill (Model D, F. J. Fitzpatrick Co., Chicago, Ill.) operated at 4100 r.p.m. without screens. The coarsely chopped material was placed in a steam jacketed kettle, 20% by weight of water added and the mixture heated to 196° F. with continuous agition. Further reduction in the size of the beet puree was accomplished in a finisher (F. H. Langsenkamp Co., Indianapolis, Ind. Model 1858) equipped with screens having 0.033-inch diameter openings. This puree was then heated to 200° F. in a steam-jacketed kettle before filling into 8 oz. jars which were then capped with a steam vacuum exhaust before heating in water at 245° F. for 45 minutes. Cooling the jars and contents in water under pressure to around 100° F. required an average of 7 minutes.

Holding time. To study the effect of holding the puree at an elevated temperature on the formation of PCA, a series of samples were taken from a large batch of well mixed puree immediately after the finishing operation and held at 200° F. for 1 to 4 hours in separate containers before filling into jars and retorting according to the standard manufacturing procedure. This range in holding times was considered to encompass any delay likely to be encountered in a commercial operation due to breakdowns, deaeration or uneven flow of product through the processing line.

Holding temperature. The effect of temperature upon the formation of PCA was determined using a similar series of samples of finished puree from a single batch to which 0.67% of glutamine had been added. These samples were held for 2 hours at temperatures ranging from 138° F. to 188° F. before heating to 200° F. and immediately filling into jars and retorting.

Glutamine content. The glutamine concentration of samples from a single batch of finished puree was varied by adding glutamine. These purees were then held at 200° F. for 2 hours before filling and retorting.

Analyses of glutamine and PCA contents. Analyses for glutamine and PCA on the finished product were made on the combined contents of several jars. Analytical procedures used to determine PCA and glutamine have been described elsewhere *(4, 6)* and the data presented are averages of triplicate determinations on duplicate samples.

RESULTS

Holding time. The effect of prolonging the processing time or holding time upon the formation of PCA in beet puree is shown in Figure 1. The rate of PCA formation appears to be a linear function of the processing time. The coefficient of correlation obtained, 0.89, was significant at the 5% level.

Holding temperature. Results obtained by varying the processing or holding temperature are shown in Figure 2. It would appear that the formation of PCA during processing is an exponential function of the processing temperature. Above

[a] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 26, 1958.

[b] Journal Paper No. 1132, New York State Agricultural Experiment Station, Cornell University, Geneva, New York.

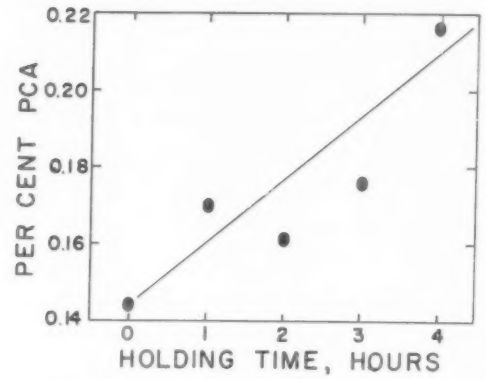

Figure 1. The effect of the holding time (200° F.) upon the formation of PCA in beet puree.

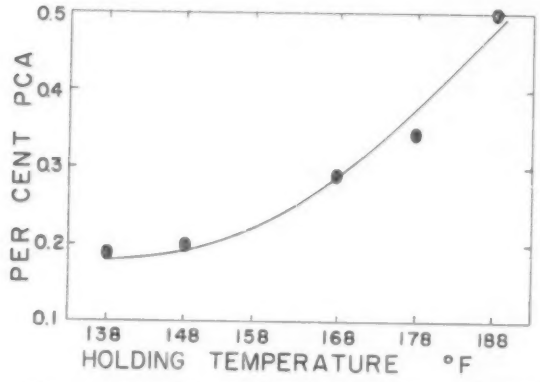

Figure 2. The effect of the holding temperature (2 hours) upon the formation of PCA in beet puree.

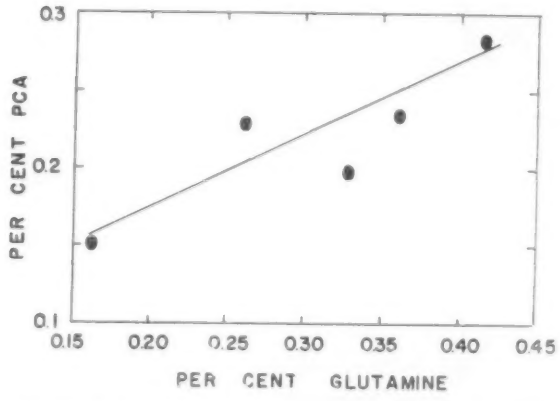

Figure 3. The effect of the glutamine concentration (Temp. 200° F., holding time, 2 hours) upon the formation of PCA in beet purees.

temperatures of 148° F., the rate of PCA formation is quite rapid. Vickery *et al. (8)* caution against the use of temperatures greater than 60° C. (140° F.) when attempting to prepare glutamine from table beets.

Glutamine content. The effect of varying the glutamine content of the beet mash upon the formation of PCA can be seen in Figure 3. These data show that under standard conditions of processing (2 hours at 200° F.) the PCA content of the finished product varies directly with the glutamine content of the raw material. The coefficient of correlation was 0.90, and was significant at the 5% level.

DISCUSSION

Data obtained on beet puree produced in the pilot plant show that the processing time, processing temperature, and the glutamine content of the raw stock significantly affects the PCA content of beet puree. A previous study *(6)* showed that high PCA concentrations contribute to an off-flavor in beet puree. Analyses for PCA showed that PCA is absent in raw beets, and PCA is to be considered, therefore, as a product of processing. As calculated from the effect of temperature on PCA formation, about 49% of the glutamine theoretically available would be destroyed by retorting. Actual glutamine analysis *(4)* showed that PCA formation is about 60% of that theoretically available due to cooking and retorting. Cooking, holding for 4 hours, and retorting resulted in the decomposition of 98% of the glutamine available. It is apparent, therefore, that raw beets containing considerable glutamine, whether from fertilizer practice *(9)*, or from cold storage *(8)*, must be processed with special care to avoid the formation of excessive PCA and off-flavor.

SUMMARY

The formation of pyrrolidonecarboxylic acid (PCA) during the manufacture of beet puree for baby food was studied on a pilot plant scale and found to be affected by the glutamine content of the beet mash and the processing times and temperatures. High concentrations of PCA can cause off-flavor, and the incidence of off-flavor may be reduced by using beets with relatively low glutamine contents and by minimizing the time pureed beets are held at elevated temperatures prior to retorting the filled containers.

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Radiation Preservation of Milk and Milk Products. VIII.

Radiation-Distillation Apparatus for using High Energy Electrons[a,b,c]

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(Manuscript received May 31, 1958)

When milk was irradiated with gamma rays from a cobalt-60 source, it was found that acceptable flavor levels could be obtained at dose levels of two million rad when certain operating conditions were maintained. These conditions consisted of the concurrent removal of volatiles by maintaining certain evaporation rates and by excluding oxygen during radiation. The limitations of dose rate which are inherent in experiments using kilocurie cobalt-60 as a source of radiation made the extension of these experiments to higher dose levels of interest. Previous studies indicated that an increase in ionization intensity or dose rate might necessitate some increase in evaporation rates; the extent of such increase, however, remained to be determined. Use of high energy electrons offered advantages over gamma- or x-rays because of greater flexibility of manipulation and because higher dose rates could be achieved. The source of high energy electrons at the Department of Food Technology at M.I.T. consists of a GE Resonant Transformer which delivers electrons 800 KVP at a beam current of 1 mA. These beam characteristics made it necessary, however, to collect a dose of two million rad by multi-passes of the milk through the beam. Therefore, sterilization of the milk was not achieved with this arrangement and this problem remains to be solved by introducing changes in the apparatus.

An electron beam of 800 KVP will penetrate only approximately 2.5 mm. of milk. This posed severe restrictions on the construction of the irradiation vessel. A rigid cover, able to withstand the atmospheric pressure outside with vacuum inside the vessel, would absorb most of the energy of the electrons. Also, a considerable velocity gradient would exist in a milk stream three millimeters thick flowing on a solid surface, and this would prevent the application of a uniform dose throughout its cross-section. Therefore, the concept of irradiation under vacuum in a closed vessel had to be abandoned with the particular electron accelerator under discussion. Instead, the processes of irradiation and of removal of volatiles were separated into two distinct phases. The milk was first irradiated at atmospheric pressure while under a helium blanket and then drawn into a flashchamber for the removal of volatiles while being boiled under vacuum.

APPARATUS

Figure 1 is a block diagram showing the principle for the arrangement which was developed. The milk flows in a closed system through the irradiation chamber to the flash evaporator for the removal of odors, through the circulation pump and the heat exchanger, which compensates for the heat losses of the evaporation, and back to the irradiation chamber. The vapors containing the off-odors are recovered as condensate from the cooler. Make-up water is fed into the system to maintain a constant milk volume. Figure 2 presents the arrangement in more detail.

A spray nozzle, 1, which contains an arrangement of stainless steel fins, to assure uniform flow, emits a spray of milk approximately 3 mm. thick into a funnel-shaped intake, 3. This spray transverses the electron beam of about 4-in. diameter which leaves the window, 2, of the 800 KVP Resonant Transformer. This arrangement is enclosed in a rectangular stain-

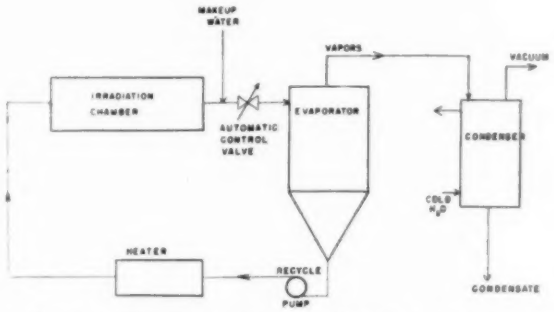


Figure 1. Diagram showing the principle of the apparatus developed.

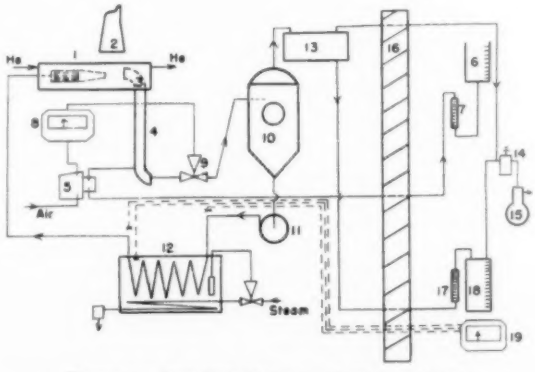


Figure 2. Detailed diagram of the apparatus.

[a] This paper reports research undertaken in cooperation with the Quartermaster Food and Container Institute for the Armed Forces, and has been assigned Number 921 in the series of papers approved for publication.

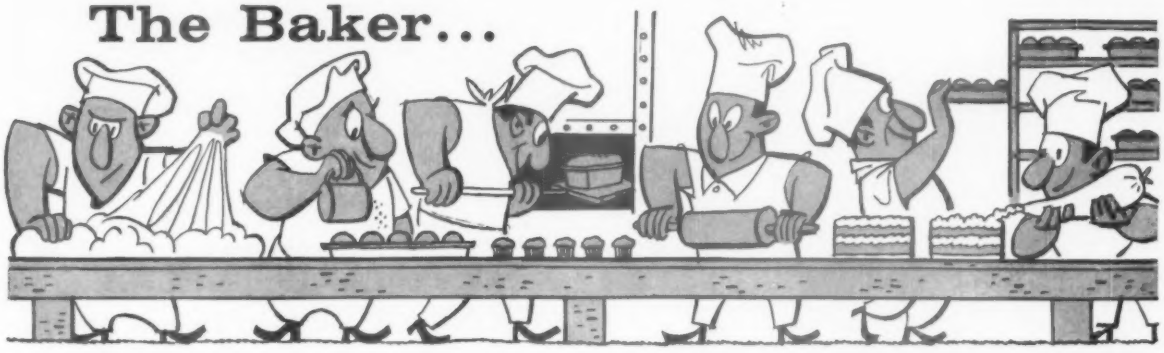
[b] Contribution Number 358 from the Department of Food Technology, M.I.T., Cambridge, Mass.

[c] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 26, 1958.

[d] Present address: Western Hemisphere Research, Inc., Marysville, Ohio.

The Butcher...

The Baker...



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less steel box, 1, through which a stream of helium flows under a pressure head of about one inch of water so as to maintain an oxygen-free atmosphere. An aluminum foil of one mil. thickness admits radiation from the window, 2, with little loss of energy.

The funnel receiving the irradiated milk continues into a vertical standpipe of 1.5-in. tubing, 3, which is calculated to give a holding time of 2 seconds when milk is pumped at a rate of 5 g.p.m. through the system.

A level transmitter, set to maintain constant level between 0–20 in. (milk), is connected to the bottom of this capacity pipe through ¼-in. stainless steel tubing. Distilled water flows from the measuring tank, 6, through a Rotameter, 7, and the level transmitter into the pipe, 3, and serves the double purpose of keeping the transmitter free from milk and of supplying make-up water to replace the condensate which is being distilled off. The impulse of the level transmitter is carried to the level control instrument, 8, which in turn activates the diaphragm valve, 9.

Through this system, milk is drawn by vacuum into the flashchamber, 10. This consists of a stainless steel cylinder of 12-in. diameter with conical bottom. Some of the volatiles are removed by flash-evaporation; the remainder of milk is returned through a sanitary Moyno pump, 11, through a heater, 12, back into the radiation vessel, 1. The heater consists of a coil 30 feet long by ¾-in. OD stainless steel tubing, with a heating surface of 6 sq. ft. One and five-tenths of a gallon of double concentrated milk are circulated through this system. By maintaining a temperature of about 50° C. during irradiation, evaporation of 190 ml./min. (3 g.p.h.) at approximately 55 mm. Hg can be maintained which will cause a temperature drop of about 6° C. in the milk returning from the flash chamber.

The heating coil, 12, is immersed in a water bath, heated by a steam coil. This coil is actuated by a temperature regulator which controls the steam valve. Under the experimental conditions outlined above, the reheating of the milk to 50° C. can be accomplished by maintaining a temperature of 72° C. in the bath.

Vapors are condensed by a tubular condenser, 13, which is cooled by tap water. Vacuum is maintained through a cartesian monostat, 14, and vacuum pump, 15. Condensate is carried through the concrete shield, 16, Rotameter, 17, and receiver, 18, which is connected by tubing with the vacuum system.

Both measuring tank, 6, and receiver, 18, are graduated and by check of flow rate through rotameters, 7, 17, as well as by total volume in both tanks, the volume of circulating milk is maintained in balance until the required dose is received. Thermocouples are installed in the water bath, 12, as well as in the intake and outlet of the heating coil, connected with a multi-point recorder, 19, for observation outside the shield.

DOSIMETRIC METHODS OF EVALUATION

Use of conventional chemical methods of dosimetry such as ferrous sulfate or dyes is difficult due to technical reasons, since, under the experimental conditions (of 5 g.p.m. in order to produce the proper spray) the positive displacement pump (Moyno) developed too much friction with such non-lubricating liquids.

Previous work has indicated that a good correlation existed between the browning reaction of irradiated milk and dose *(1)*. It was therefore believed that this method would be most appropriate for this particular purpose. A total dose of 1.86×10^6 rad was to be absorbed by the milk during 30–130 passes through the electron beam. Runs were made using 7 liters of homogenized milk, circulated through the system at 5 g.p.m. Application of 1.86×10^6 rad was found to require 18 minutes when a beam current of 0.95 mA was applied. Within the time limit studied, i.e., 10–40 minutes at beam currents of 0.5–1 mA, a linear relationship was observed of these two parameters which can be expressed as:

$$\text{Minutes} = (76.5-52) \times \text{mA beam current.}$$

The validity of using the browning reaction for dosimetry is supported by the following considerations: By radiating conventional dosimeters on a conveyor belt traveling across the electron beam, it was found that a conveyor speed of 8.4 ft./min. was required to obtain a dose of 1.86×10^6 rad. Considering that electrons of 800 KVP will penetrate approximately 2.5 mm. of milk and that only two-thirds of the beam cross-section is absorbed by the milk, one finds, for the conditions of 0.95 mA beam current and 18 minutes' exposure, that 7.8 liters of milk will receive the required dose of 1.86×10^6 rad. The total volume of milk circulating in the system is 7.0 liters. A slight loss of potential by the electrons when passing through the window material of the irradiation chamber, may account for this difference of 7.8 vs. 7.0 liters.

Dose rates up to 10^5 rad per minute can be applied with the 8 KVP Resonant Transformer under these experimental conditions. None of the plastic films used on the window of the radiation chamber was found to be resistant enough under these conditions of radiation, since the actual dose received at the window is in the billion rad range. Neither mylar nor polyethylene films remained stable. Aluminum sheets of one mil. thickness were then used and found to withstand radiation energies as used in these experiments.

CONCLUSIONS

The feasibility of irradiating milk with high energy electrons under conditions which permit the control of off-flavors has been shown. The apparatus described herein was designed to produce data similar to those previously obtained with gamma rays. It was not designed, however, to represent the final solution to the problem of milk sterilization. The arrangement of collecting a dose of approximately two million rad by repeated passage through the field was necessitated by the relatively low power output available with the 800 KVP accelerator and should not be taken as a final solution.

It was found that the increase in radiation energy from 5000 rad/min. to 100,000 rad/min. did not require proportional increases in evaporation rates and it is believed that the increase from 0.8 to 2.2 ml./ml./h. might be further diminished by a more thorough knowledge of processing conditions. Experiments carried out with raw milk showed that, as expected, no sterilization was achieved when a total of 1.86×10^6 rad was absorbed. Pre-sterilization of the apparatus with steam would not change this situation. It is hoped, at a later time, that the apparatus can be reconstructed on similar principles to permit irradiation that might lead to sterile milk.

Acknowledgments

The authors are appreciative of financial assistance in the form of grants-in-aid from the following organizations which made a part of this program possible: Armour and Company,

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Effects of Environmental and Processing Factors on the Citral Content of Lemon Oil[a]

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(Manuscript received July 21, 1958)

The discoveries in this laboratory *(8)* and in the laboratory of the Canadian Department of National Health and Welfare *(6)* of specific methods of analysis for citral have made available much needed tools for the objective evaluation of the quality of lemon oils and lemon products and for following the effects exerted by agronomic and processing variables on the citral content of these products. In the past, citral determinations on lemon oils were based on a total carbonyl analysis either with phenylhydrazine or with hydroxylamine *(4)* both of which methods are nonspecific toward individual aldehydes and ketones. Although other compounds (*viz.*, aldehydes, ketones, esters and alcohols) *(3)* contribute to the natural aroma of lemons, citral is recognized as the most important component and is generally assumed to represent about 80% of the total carbonyl content of the peel oil. The specific citral method developed in our laboratory employs a vanillin-piperidine reagent mixture for the development of a green complex which appears to be specific for the alpha-beta unsaturated terpene aldehydes and ketones. Color intensity is proportional to citral concentration and can be measured conveniently with a spectrophotometer at 605 mμ. A simple colorimeter equipped with a filter giving maximum transmission above 590 mμ should be adequate, although such equipment was not used in our experiments.

Lemon oil occurs in small ductless sacs imbedded in the colored surface or "flavedo" layer of the peel. When the peel is compressed, twisted, or the surface is punctured or rasped the oil is released. Commercially, the oil is recovered as a water emulsion followed by centrifugation. Although there are many methods for recovering the oil emulsion from the fruit, this paper will be concerned only with the screw press process in which spent peel halves are passed through a horizontal tapered screw which rotates within a close fitting cone having perforations along the bottom. The peel in passing through the screw is crushed, pressed against the perforations, and expelled from the apex end of the cone; the oil emulsion passes through the holes in the cone and is collected separately. The oil emulsion is separated with a centrifuge (sludger) operating at 6,000–8,000 r.p.m. and the recovered oil phase clarified in a centrifuge (polisher) at 16,000–18,000 r.p.m. *(3)*. Finally, waxes are removed by holding the oil at reduced temperature (winterizing) and then centrifuging off the deposit that is thrown down.

Citral losses have been attributed to all stages of processing although the actual values have not been determined analytically. No determinations of citral or total carbonyl in the oil in the fruit have been made previously because no satisfactory method of analysis has been available. Kesterson *(5)* has shown with orange oil that excess water wash in the initial extraction step results in lower total carbonyl content both by comparing 4 types of extraction and by modifying water to recovered oil ratios in the same extractors. Guenther *(2)* has stated that the quality of citrus oils is affected by the amount of wash water used in the extraction step. These losses cannot be explained strictly on the basis of a distribution coefficient effect for citral and the C_8–C_{11} saturated aliphatic aldehydes, *i.e.*, between water and the terpene hydrocarbon mixture which makes up approximately 90% of lemon oil. A selective surface adsorptive activity in the emulsion system might cause losses in carbonyls but so far as we know this has not been investigated. Berlin, Davankov, and Kalliopin *(1)* have demon-

[a] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 26, 1958.

strated that the addition of emulsifier increases the rate of oxidation of camphene in a non-homogeneous aqueous system. Similarly, the air oxidation of citral in lemon oil should be affected by emulsification. However, it is hard to explain how, in a system where water is already in huge excess, further increases in water can have such a profound effect.

Although no substantiating data are available it has been assumed generally that evaporative or oxidative losses in carbonyls occur in the sludging, polishing and dewaxing processing steps as well as in the initial extraction step.

This paper presents citral data, determined by the vanillin-piperidine method, collected in order to establish the actual losses in citral in the various processing stages from the fruit to the finished oil. An attempt also was made to determine in model systems the effects of certain individual components in the juice and, to a limited extent, the effects of cultural factors on the citral content of the oil in the fruit and in the finished oil.

METHODS

Analyses for citral in oil samples by the vanillin-piperidine method *(8)* were made by allowing a 2 ml. aliquot of a suitable dilution of the oil in commercial absolute methanol or ethanol (500/1 dilution is generally adequate) to react at room temperature with 4 ml. of a freshly prepared mixture of equal volumes of 1 molar vanillin and 7% v/v piperidine in commercial absolute methanol or ethanol. After 55 minutes the absorbance was determined at 605 mμ in a 1 cm. borosilicate cuvette with a DU spectrophotometer. The per cent citral was calculated from a standard curve obtained with a specially purified sample of citral.

For determining the citral content of oil in the peel of individual fruits, oil is collected from sections of the peel in the following manner. A 2 in. square piece of aluminum foil is laid across the top of a tared weighing bottle (having an outside cap) and a hole the size of the top of the weighing bottle is punched through the foil so that the turned-down edges press against the inner walls of the weighing bottle and hold the foil in place. This foil collar prevents oil from spattering on the lip and outer walls of the bottle. Sections of the peel approximately ½ by 4 in. are cut away from the fleshy part of the fruit without releasing juices from the flesh, if possible. The surface of the peel is wiped with tissue or a dry cloth and the peel is twisted with the flavedo side over the weighing bottle so that the oil sprays into the bottle. The peel is held slightly to the side of the bottle so that liquid dripping from the inner surface of the peel does not fall into the sample. The foil is then discarded and the bottle is immediately capped and weighed.

The sample is washed with commercial absolute methanol or ethanol into a 10-ml. volumetric flask and diluted to volume. One or two ml. aliquots of this solution are then used for the citral determination. For samples weighing less than 10 mg. a 2-ml. aliquot is used and for samples weighing from 10 to 30 mg. a 1-ml. aliquot is used.

RESULTS AND DISCUSSION

Analyses of oil in the peel obtained from different portions of the same fruit indicated wide and random variations over the fruit surface (Table 1). Subsequently, all analyses on individual fruits were run on oil obtained from the equatorial belt. Wide variations in citral content were observed also for fruit picked from the same tree to fit the same ring size. There was no apparent correlation with maturity among these samples (color grades: dark green, light green, silver and tree ripe). However, a sufficiently large sampling within each color grade might show some correlation. This wide variation in data on individual fruits may be in part the fault of the method of recovering the oil sample. Consequently, probably only gross differences obtained by averaging a large number of samples are significant. The fruit collected for maturity comparisons were taken from a grove in the Corona area (inland, semi-arid conditions) and from two groves in the Ventura area (coastal, humid conditions). One of the Ventura groves was a 25-year-old planting, the other a 5-year-old planting; the Corona grove was about 40 years old. Now, if the combined data for all of the fruit from the three groves is considered there does appear to be correlation of citral content with growing area (c.f., Table 2). It is clearly apparent that the citral content of the oil in the fruit from the coastal groves is much higher than from the inland, arid region.

TABLE 1

Citral content of lemon peel oil hand-expressed from segments of fruit peel

Section sampled	Citral, % (by vanillin-piperidine method)		
	Fruit 1	Fruit 2	Fruit 3
Stem end	3.60	4.63	3.38
Equatorial belt	4.06	4.23	2.54
Stylar end	3.93	2.50	3.04

TABLE 2

Citral content of hand-expressed lemon peel oil from California coastal and inland areas

Geographical region	Age of grove, years, approx.	No. of fruit sampled	Citral, %	
			Range	Av.
Corona (inland)	40	19	0.96–3.10	2.07
Ventura (coastal)	25	16	3.28–5.20	4.01
Ventura (coastal)	5	15	3.41–6.54	4.62

The effect of growing area is further demonstrated in Table 3 where data are summarized for domestic lemon oils from four growing areas in the southwest. These oils were processed in December, 1957 by the same plant presumably under identical conditions. The citral content of the lemon oil from arid inland regions is distinctly lower than that of oil from the more humid coastal areas. The total carbonyl values (phenylhydrazine method *(4)* calculated as citral) and the corresponding ratios of citral to total carbonyl calculated as citral are also given in Table 3.

TABLE 3

Citral content of processed lemon oils—effect of growing area

Growing area	Total carbonyl (as citral)	Citral	Ratio: citral / total carbonyl
	%	%	
Ventura, Cal.	3.16	2.42	0.77
Fullerton, Cal.	3.35	2.56	0.76
San Joaquin, Cal.	2.28	1.88	0.80
Yuma, Ariz.	2.74	1.98	0.80

When sufficient data have been collected this ratio may prove to be a useful quality index for lemon oils.

Poore *(7)* has presented data demonstrating a similar relationship between total carbonyl content and the geographical location of the groves. Lemon oils from the humid coastal areas consistently ran higher in total carbonyl than oils from the more arid regions.

Unfortunately, there appears to be an inverse relationship between total carbonyl content and the optical rotation of domestic lemon oils. Oils having particularly high carbonyl content generally do not meet the U. S. Pharmacopoeia requirements *(9)* for optical rotation. The actual citral content also follows this trend as shown in Table 4 where two extremes are compared with a sample of lemon oil having average optical rotation. The high rotation oil contained only 1% citral whereas the low rotation oil contained 2.3%.

TABLE 4

Relationship of citral content to optical rotation of California lemon oil

Optical rotation a_D^{20}	Citral	Total carbonyl as citral
	%	%
+51.8	2.27	3.55
+58.8	1.77	2.95
+80.9	1.00	1.44

Approximately a 25% loss in citral was observed to occur during lemon oil processing under ideal conditions. In one example the citral content of oil collected by hand expression from seven lemons (pooled for the analysis) selected at random from a processing run was found to be 3.2% whereas the citral content of the processed oil was 2.4%. Under less favorable conditions the losses probably approach 50%. Kesterson reports *(5)* that in a Florida plant processing orange oil a reduction in the amount of water added in the extraction step resulted in a 52% increase in the total aldehyde content of the processed oil.

An investigation was made to determine what the losses in citral content actually are in the various stages of a typical lemon oil run. Raw lemon oil was sampled and then run through the recleaning and dewaxing (winterizing) steps and samples removed at each step for analysis. From the results summarized in Table 5 it appears that there is no appreciable loss in citral in these operations. The preceding step in the process, the initial slow-speed centrifugation (sludging) was next examined by diverting emulsion from the screw presses to two sludgers, one

TABLE 5

Effect of recleaning and dewaxing steps on citral content of lemon oil

Sample	Total carbonyl as citral	Citral	Ratio: citral / total carbonyl
	%		
Raw lemon oil from sludger	3.08	2.63	0.85
Sample above recleaned	3.12	2.63	0.84
Sample above dewaxed	3.08	2.59	0.84

TABLE 6

Effect of open and closed sludgers on citral content of lemon oils

Emulsion treatment	Citral
	%
Open sludger followed by Westphalia polisher	2.66
Hermetically sealed sludger followed by Westphalia polisher	2.66

an open sludger and the other a hermetically sealed unit. The two oil phases were then passed through a Westphalia polisher centrifuge and analyzed for citral. The citral contents of the two oils were identical (Table 6). Evidently the residence time of the oils in the centrifuges is so short that citral losses by evaporation or by exposure to air are negligible. From the results in Table 5 and 6 it is evident that the major citral losses must occur in processing during the initial extraction step in the screw press process when the oil as fine droplets or emulsion is in intimate contact with pulp and juice components.

Some of the individual components of the juice and selected materials were then contacted with samples of lemon oil in the laboratory as model systems to determine their effects singly on the citral content of lemon oils. The treatments included shaking the oil with water, with 1% citric acid solution, and with 5% sodium chloride solution, contacting the oil in a blender at low speeds with water and with 1% citric acid solution containing 0.2% glutamic acid. The results summarized in Table 7 show that under the physical conditions used in the laboratory test none of the materials tested appreciably affected the citral content of the oil. In a separate experiment in which a sample of lemon oil was shaken with four fresh batches of five times its volume of water followed between each treatment by centrifugation through a laboratory scale Westphalia polisher no significant change was observed in the citral content of the oil (Table 8).

TABLE 7

Model systems

Effect of various treatments on citral content of lemon oil

Oil treatment	Treated oil		Control	
	Total carbonyl	Citral	Total carbonyl	Citral
	%	%	%	
(1) Shaken with 3 vol. water	3.19	2.67	3.08	2.63
(2) 3 vol. water, in blender low speed, 30 min	3.27	2.56	3.08	2.63
(3) Shaken with ½ vol. 5% NaCl solution	3.12	2.68	3.08	2.63
(4) Shaken with 3 vol. 1% citric acid	3.15	2.69	3.08	2.63
(5) 5 vol. 1% citric acid sol. containing 0.2% glutamic acid, blender, low speed 30 min	.....	2.43	.....	2.44

TABLE 8

Effect of successive water washes on citral content of lemon oil

Oil sample	Total carbonyl as citral	Citral
	%	%
Original oil (A)	3.12	2.33
(A) Shaken with 5 vol. water (B)	.....	2.42
(B) Shaken with 5 vol. water (C)	.....	2.42
(C) Shaken with 5 vol. water (D)	.....	2.42
(D) Shaken with 5 vol. water	3.17	2.42

SUMMARY AND CONCLUSIONS

The evidence gathered in this study on the actual citral content of oils from individual lemons and of processed lemon oils confirms the observation made earlier by Poore *(9) viz.*, that the total carbonyl content consistently runs higher in processed oils from the coastal area than in oils from the arid inland areas.

In commercial lemon oil production only negligible losses in citral occur in the sludging, polishing and dewaxing steps. The major loss which may be as high as 50% under unfavorable conditions occurs during the expression of the water and oil emulsion from the peel. Tests with water and water solutions of citric acid, salt, glutamic acid, and exposure during these tests of the mixtures to air in the laboratory have eliminated these components of the juices as individual agents responsible for losses in citral. The effect exerted by excess water in the screw press process apparently is not a simple partition phenomenon but somehow involves materials in the juice and pulp other than those mentioned which have specific affinities toward the carbonyl compounds. It is not known whether this is a simple adsorption process, requires the formation of an intermediate complex with other materials or involves enzymatic action.

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Studies on the Freezing and Defrosting of Cakes[a]

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(Manuscript received July 26, 1958)

Among bakery products that are successfully frozen on a commercial scale for delayed marketing, cakes probably rank second only to pies of all kinds in amounts processed in this manner. Several reports *(1, 3, 4, 6, 11)* attest to the relative tolerance cakes have toward variations in freezing and defrosting practices that are so important with bread and related items *(1, 8)*. Good results appear to be obtained with a rather wide range of freezing, storage, or defrosting conditions. However, little information of a critical nature has been published to show whether variations in these factors may have detectable or even significant effects on quality features of the final product. Moreover, only limited information has been published to show how fast cakes of various types will freeze or defrost under a variety of temperature, icing, and packaging conditions. As the volume of frozen bakery products increases and as the sizes of freezing installations increase from year to year, the need for detailed information on a wide variety of frozen products also increases.

The present report gives time-temperature results for the freezing and defrosting of several types of cake obtained under a variety of experimental condi-

[a] Presented at meeting of Institute of Food Technologists, Chicago, Illinois, May 27, 1958.

[b] Western Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Albany 10, California.

tions considered to be representative of major commercial interest. Effects of temperature, air velocity, and packaging are presented and discussed for iced and plain chocolate or yellow layer cakes, angel food, chiffon, and pound cakes. Observations were also made on the effects of slow and fast freezing on quality characteristics of the cakes.

MATERIALS AND METHODS

For the most part, cakes were commercially produced and selected to represent the major basic types normally encountered in commercial operations. All were relatively high-ratio or otherwise sufficiently rich in formulation that they would be considered as medium to high quality representatives of their types. Most of the cakes were obtained from a single retail bakery within 2 to 3 hours after baking. Some of those used for taste-panel comparisons were prepared in our own laboratory from the same or closely similar formulas.

Most of the work with layer cakes was conducted with standard 7-inch layers, although some results were also obtained with 8-inch and 10-inch layers. Icings were typical butter-cream and chocolate fudge types. Angel food and chiffon cakes were baked in 9-inch tube pans and not iced. A few observations were also made with 6-inch angel food cakes baked in tube pans. Pound cakes were scaled at 14 ounces of batter and baked in corrugated glassine pan liners to yield a finished cake measuring about 7 x 3¼ x about 2½ inches high. In a few instances pound cakes were baked in rectangular aluminum-foil pans of approximately the same size.

Cellophane used for wrapping was a standard 300 MST-51, heat-sealing and moisture-resistant grade of transparent film. Paperboard boxes were of bleached, printed stock and of the following dimensions (in inches) for the various sizes of cakes:

	W	L	H
7-inch layer cakes	7½	7½	3½
8-inch layer cakes	9	9	3½
6-inch angel food cakes	7½	7½	3½
9-inch angel food and chiffon cakes	9	9	3½
Pound cakes	7½	4¼	3½

Temperature measurements inside the cakes were made by means of thermocouples and an automatic recording potentiometer, as described previously *(7)*. In layer cakes, thermocouples were placed at central points within and between the two layers as illustrated in Figure 1. In pound cakes, duplicate thermocouples were inserted as near as possible to the center of the rectangular loaves. In angel food and chiffon cakes, one thermocouple was inserted as near as possible to the center of the ring of cake and another in an equivalent position in the opposite half of the cake. The time-temperature curves presented or from which data were tabulated are composite curves of 2 to 4 separate runs in each of which duplicate cakes were run.

The freezing and defrosting equipment used was also described previously *(7, 9)* except for the experiments in which so called still air was used. For these runs the cakes were placed in cold rooms maintained automatically within ± 2° F. of the specified tempertaure. Air movement was just sufficient to maintain uniformity of temperature within the room and was estimated to be appreciably less than 100 linear feet per minute at the location of the cakes being frozen. In defrosting, only one air velocity was used; this amounted to approximately 150 feet per minute, as measured in the empty chamber with a pinwheel anemometer. All cakes were equilibrated to 0° F. before defrosting experiments were begun.

Organoleptic comparisons were made by a trained, non-expert panel. Samples were ranked in order of freshness with respect to texture and/or flavor. Results were evaluated by Duncan's multiple range test *(5)* using a 5% level of significance.

Figure 1. Bottom: Thermocouples placed and held in position at the center of each layer and between the layers. Top: The cake re-assembled and held together with plastic screen.

RESULTS

Because the information collected was so voluminous, a presentation in the form of a few illustrative time-temperature curves plus tables grouped according to freezing and defrosting conditions and to cake type was selected as perhaps the most efficient. Not all of the experimental variations were studied with each type of cake. The variations pertaining to each experiment are listed in the individual figures and their legends or in the tables. In layer cakes, only the temperatures at the center of the cake, between the layers, are reported. In general, however, the top layer cooled slightly faster than the bottom layer and both layers cooled faster than the point between the layers, as would be expected.

Freezing rates and times under various conditions. Figures 2 and 3 show the results obtained with iced and plain layer cakes, angel food, and pound cakes in a −20° F. freezer using about 650 f.p.m. air velocity. At these relatively rapid rates of freezing, the curves for most of the cakes are smooth, and show little evidence of passage through a zone of liberation of latent heat of fusion. Two of the curves in Figure 2 show some evidence of freezing points at either or both 3° F. and 9° to 10° F. In both cases, however, the thermocouples were imbedded in the icing between the layers of cake, so that the inflections may not be a true reflection of changes occurring in the cake crumb. Clear evidence of freezing zones and of recovery from supercooling will be seen later.

Several other features of interest are illustrated in Figures 2 and 3. The relatively small effect of the fairly snug cellophane wrap on the cooling rates of plain cakes is less than expected from results obtained previously with wrapped and unwrapped bread during freezing with low and medium velocity air (about 150 and 700 f.p.m.) *(7)*. The larger effect due to packaging in paperboard boxes is more in line with expectations. Icings on cakes generally impeded heat flow to approximately the same extent as paperboard boxes, although subsequent data illustrate the correspondence better. The cream type icing was consistently a better insulator than the fudge icing.

Under comparable conditions the smaller but more dense pound cakes (Figure 3) cooled more slowly than the layer cakes and at about the same rate as the still larger and less dense angel food cakes, excepting only when the latter were enclosed in a paperboard box.

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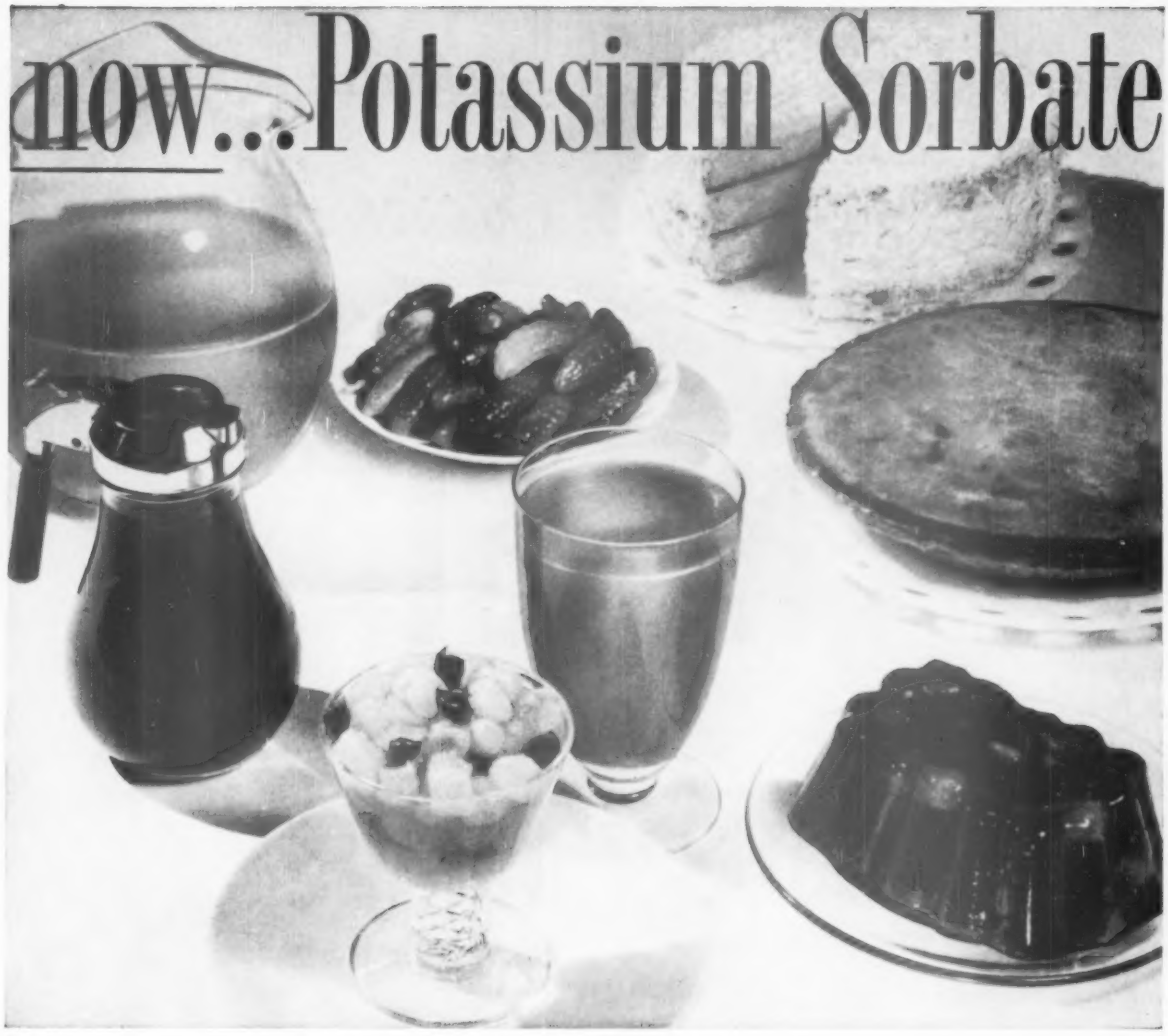

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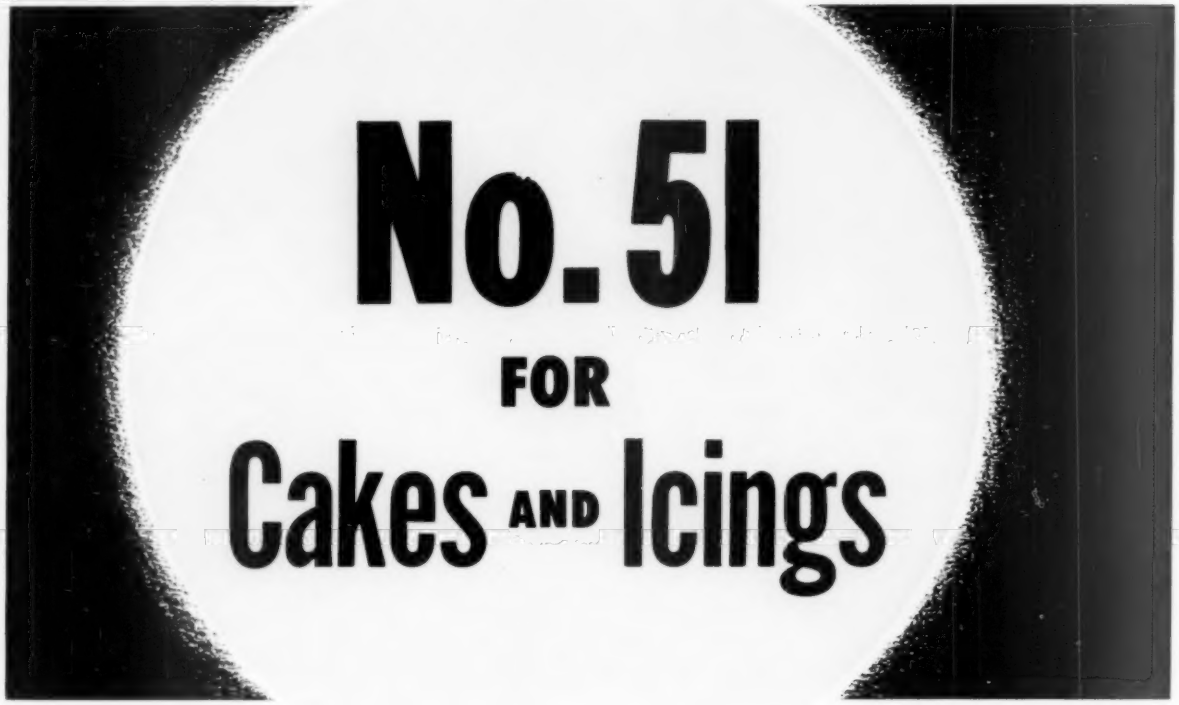

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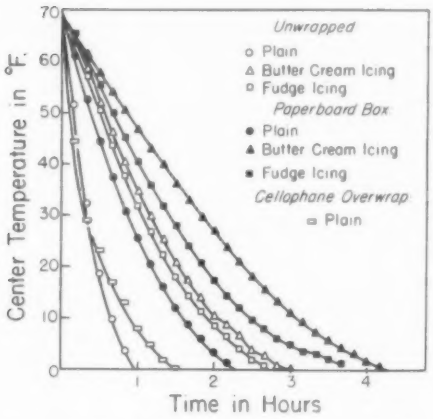

Figure 2. Cooling curves for 7-inch layer cakes in freezer held at −20° F. and with about 650 f.p.m. air velocity.

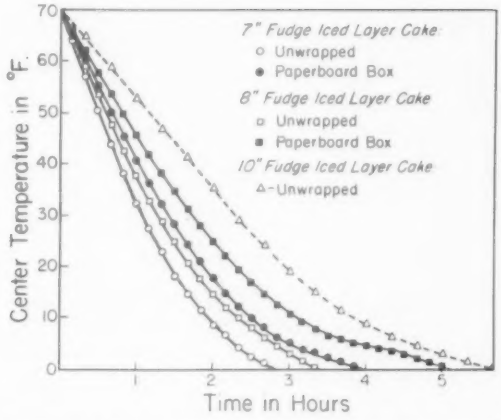

Figure 4. Cooling curves for layer cakes of different sizes in freezer held at −20° F. and with about 650 f.p.m. air velocity.

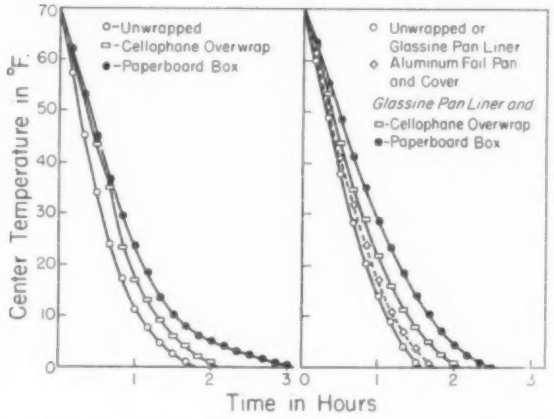

Figure 3. Cooling curves for 9-inch angel food (left) and pound cakes (right) in freezer held at −20° F. and with about 650 f.p.m. air velocity.

Attention should be called to the fact that cooling rates for pound cakes baked in aluminum foil pans without a pan liner were almost identical to cakes with no covering whatsoever or with the snug-fitting glassine pan liners. In other words, heat flow through snug-fitting wrapping or packaging materials is definitely faster than across even a small air space between the cake surface and the wrapper.

In Figure 4, the increasing size of the different layer cakes slowed cooling to a degree proportional to cake size. In fact, the cooling time from 70° to 0° F., was directly proportional to the square of the diameter.

Cooling curves for the various cakes under other temperatures and air flow conditions, in general, are quite similar to those shown in Figures 2 to 4. Therefore, the remainder of the results collected are presented in tabular form. Tables 1 and 2 list freezing times for the various cakes in freezers maintained at −20° F., with two rates of air flow (less than 100 f.p.m. and about 650 f.p.m.) Tables 3 and 4 give similar data for freezers maintained at 0° F. and using the same high and low air velocities. Freezing times are given for the terminal temperatures of 10° and 0° F. in Tables 1 and 2 in order to show the drastic slowing in freezing rate as the freezing gradient became small and as heat of fusion effects became operative. For Tables 3 and 4 the terminal temperature of 5° F. was used in place of 0° F. because of the obvious impracticability of measuring the time required for the product center-temperature to become equal to the freezer temperature.

Cooling times for the various cakes were significantly increased either by the decrease in the rate of air flow or by the increase in freezer temperature. These effects were greater for the increase in freezer temperature, but all were somewhat erratic, specially in cooling times to below 10° F. Cooling times in the temperature region between 0° and 10° F., often were lengthened by liberation of the heat of fusion.

The observation that packaged cakes cooled significantly faster at the higher air velocity is somewhat surprising. This

TABLE 1

Times required to cool cakes from 70° F. to 10° F. and to 0° F. (center temperatures) in a freezer maintained at −20° F., and with about 650 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	70° to 10° F.		70° to 0° F.	
		Hr.	Min.	Hr.	Min.
7-inch layer	Plain, unwrapped	0	39	0	58
7-inch layer	Plain, cellophane wrapped	0	55	1	32
7-inch layer	Plain, paperboard box	1	36	2	17
7-inch layer	Butter-cream icing, unwrapped	2	2	3	2
7-inch layer	Butter-cream icing, paperboard box	3	6	4	16
7-inch layer	Fudge icing, unwrapped	1	55	2	46
7-inch layer	Fudge icing, paperboard box	2	29	3	52
8-inch layer	Fudge icing, unwrapped	2	19	3	20
8-inch layer	Fudge icing, paperboard box	3	6	5	4
9-inch angel food	Unwrapped	1	4	1	50
9-inch angel food	Cellophane overwrap	1	17	2	6
9-inch angel food	Paperboard box	1	31	3	4
Pound cake	Unwrapped or glassine pan liner	1	8	1	36
Pound cake	Aluminum foil pan and cover	1	13	1	45
Pound cake	Glassine pan liner plus cellophane overwrap	1	24	2	4
Pound cake	Glassine pan-liner plus paperboard box	1	41	2	32

TABLE 2

Times required to cool cakes from 70° F. to 10° F. and to 0° F. (center temperatures) in a freezer maintained at −20° F. and with less than 100 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	70° to 10° F.		70° to 0° F.	
		Hr.	Min.	Hr.	Min.
7-inch layer	Plain, unwrapped	2	28	4	26
7-inch layer	Plain, paperboard box	2	45	3	56
7-inch layer	Butter-cream icing, unwrapped	2	59	4	26
7-inch layer	Butter-cream icing, paperboard box	3	41	5	12
7-inch layer	Fudge icing, unwrapped	3	0	4	40
7-inch layer	Fudge icing, paperboard box	3	32	5	12
6-inch angel food	Unwrapped	1	5	2	12
9-inch angel food	Unwrapped	1	19	2	48
9-inch angel food	Paperboard box	2	26	4	20
9-inch chiffon	Paperboard box	2	57	4	38
Pound cake	Unwrapped or glassine pan liner	1	31	2	12
Pound cake	Glassine pan liner plus paperboard box	2	4	2	47

TABLE 3

Times required to cool cakes from 70° F. to 10° F. and to 5° F. (center temperatures) in a freezer maintained at 0° F. and with about 650 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	70° to 10° F.		70° to 5° F.	
		Hr.	Min.	Hr.	Min.
7-inch layer	Plain, unwrapped	2	8	2	48
7-inch layer	Plain, paperboard box	3	0	5	40
7-inch layer	Butter-cream icing, unwrapped	3	28	4	30
7-inch layer	Butter-cream icing, paperboard box	4	28	5	50
7-inch layer	Fudge icing, unwrapped	3	40	4	0
7-inch layer	Fudge icing, paperboard box	4	16	5	22
9-inch angel food	Unwrapped	1	40	3	40
9-inch angel food	Paperboard box	2	14	5	8
Pound cake	Unwrapped or glassine pan liner	1	44	2	15
Pound cake	Glassine pan liner plus paperboard box	2	36	3	20

TABLE 4

Times required to cool cakes from 70° F. to 10° F. and to 5° F. (center temperatures) in a freezer maintained at 0° F. and with less than 100 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	70° to 10° F.		70° to 5° F.	
		Hr.	Min.	Hr.	Min.
7-inch layer	Plain, unwrapped	3	0	4	20
7-inch layer	Plain, paperboard box	4	8	5	28
7-inch layer	Butter-cream icing, unwrapped	4	30	5	32
7-inch layer	Butter-cream icing, paperboard box	5	38	7	6
7-inch layer	Fudge icing, unwrapped	4	10	5	20
7-inch layer	Fudge icing, paperboard box	5	22	7	6
9-inch angel food	Unwrapped	3	4	5	0
9-inch angel food	Paperboard box	4	20	6	50
Pound cake	Unwrapped or glassine pan liner	2	30	3	12
Pound cake	Glassine pan liner plus paperboard box	3	20	4	26

would not have been predicted from studies conducted previously with wrapped bread *(7)* in which little difference was found between results obtained using air moving at about 200 and about 700 f.p.m. It is possible that the liberation of latent heat generally observed during the freezing of bread may have caused the apparent difference between packaged bread and cake in regard to the relationships of cooling rate to air velocity. With cakes, packaged or not, supercooling is normally rather persistent and latent zones are usually quite short if present at all. Disruption of smooth cooling curves may have caused the effect of air velocity on wrapped bread to be missed.

In a number of instances cooling curves showing recovery from supercooling provided information regarding possible freezing points for the cakes. A danger in acceptance of such evidence of a freezing point is illustrated in Figure 5 which shows the individual cooling curves for angel food cakes in a paperboard box. The curves labeled 1 and 2 in Figure 5 were obtained from separate thermocouples in the same cake. Thermocouples 3 and 4 were in another cake. The recovery from supercooling shown by thermocouples 1 and 3 is much attenuated and delayed, especially for thermocouple No. 1. It may be possible that non-uniformities in the cake crumb caused the erratic temperature behavior, but this is much less

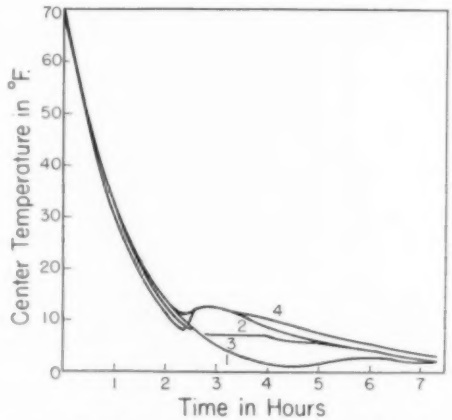

Figure 5. Cooling curves for two 9-inch angel food cakes in paperboard boxes in freezer held at 0° F. and with about 650 f.p.m. air velocity. Thermocouples 1 and 2 were placed in one cake and thermocouples 3 and 4 were in the other.

likely than supercooling effects. The high sugar and soluble protein content of the small amount of free water in the cake crumb make supercooling a likely occurrence. However, if something should trigger crystallization at just the right instant in the immediate vicinity of the tiny thermocouple (30-gauge wire), a substantial temperature rise could occur. Crystallization in a region slightly inward or slightly outward from the thermocouple would be only partly reflected by the response of the thermocouple and an attenuated or delayed temperature record would result.

On the basis of inflections in cooling curves for the various cakes, crude estimates of nominal freezing points can be listed as follows:

Cake type	Nominal freezing point, ° F.
Chiffon	15
Angel food	12.5
Yellow layer	3–5
Pound	2

Very likely these temperatures can have little significance with respect to connotations usually ascribed to freezing points of liquids or of dilute solutions, but they are useful to designate temperature regions in which cooling rates can be significantly affected by heat of fusion effects. It must also be emphasized that these nominal freezing points apply only to cakes having the same or closely similar composition to the ones used in the present study.

Defrosting rates and times under various conditions. The illustrative defrosting curves for layer cakes in Figure 6 show approximately the same relationships with each other that were found in the freezing experiments, Figure 6. That is, packaging a plain cake in a paperboard box delays defrosting about the same amount as putting an icing on the cake. Fudge icing delays defrosting less than the butter cream type. Unwrapped and paperboard packaged plain layer cakes require about the same time to defrost as the angel food cakes, whose curves are shown in Figure 7. The paperboard box delayed defrosting of angel food cakes less than it did pound cakes in this particular experiment.

Defrosting at 80° F. and with only gentle air movement (about 150 f.p.m. air) is the closest the experimental conditions used came to average room conditions. While approximately 3 hours were necessary for the temperature at the center of the cakes to come up to 70° F., the cakes could very well be considered satisfactorily defrosted in about half this time. A center temperature near 50° F. probably would not be considered objectionable by most people and within a few minutes after slicing of a cake for serving the temperature of even the cool, central portions will rise to nearly the prevailing room temperature.

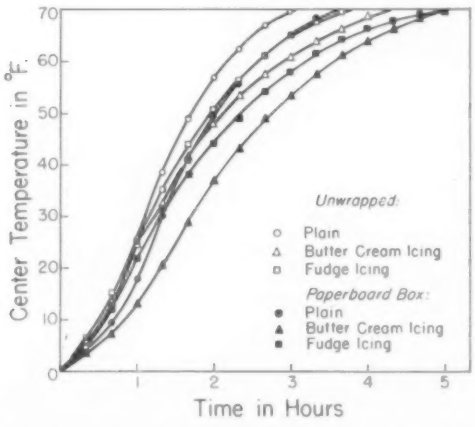

Figure 6. Warming curves for 7-inch layer cakes at 80° F. and about 150 f.p.m. air velocity.

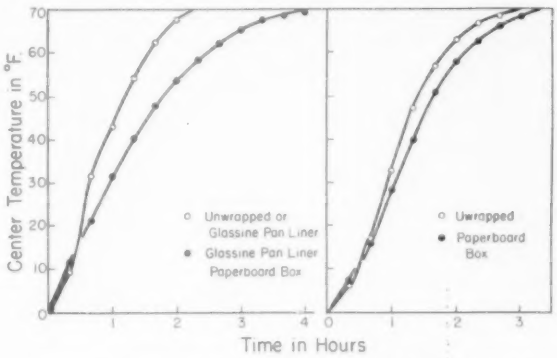

Figure 7. Warming curves for 9-inch angel food (right) and pound cakes (left) at 80° F. and about 150 f.p.m. air velocity.

Defrosting times of the various cakes under the temperature and air flow conditions used are shown in Tables 5–7. The defrosting times are accelerated a great deal more by a 20° F. increase in defrosting temperature from 80° F. to 100° F. than for a similar increase from 100° to 120° F., in spite of a greater temperature gradient. This is due to the increase in air film resistance at the higher temperatures. For all of the cakes, increasing the defrosting temperature from 80° F. to 100° F. caused the defrosting time (to 70° F.) to be cut approximately in half. The increase in temperature from 100° F. to 120° F. produced much smaller effects. The 100° F. defrosting temperature is pretty close to a maximum temperature that most icings can tolerate before they become excessively soft and will sag or run. Results at 120° F., therefore, were obtained only for the cakes without icings (Table 7).

Freezing of pound cakes in shipping cartons. A simplification of handling procedures, by packing cakes in shipping cartons before freezing, is obviously desirable in commercial freezing of cakes for wholesale distribution in the frozen state. Aside from the question as to whether the delayed freezing of the cakes would have a significant effect on quality, the principal consideration concerns just how much the freezing of the cakes would be delayed. Some information on this question is supplied by the following experiment.

Twelve pound-cakes baked in aluminum foil pans, which were closed with laminated aluminum-foil-waxed-paperboard lids, were packed in a corrugated cardboard shipping carton. The cakes were placed in 4 rows, each containing 3 cakes, as indicated diagrammatically in Figure 8. The rows were separated by means of corrugated cardboard inserts, but the cakes within each row were not separated by any means other than about an inch of air space. Thermocouples were inserted into the center of each of the cakes except the one in position 11 (the 12th thermocouple available was suspended in the freezer itself to monitor the temperature prevailing during the test). The carton was then placed on a solid wooden shelf within the cold room used as a freezer. At least six inches of unobstructed space was provided on all sides and top of the carton. Results obtained at a freezer temperature of −20° (at less than 100 f.p.m. air velocity) are shown, in part, in Figure 8. A similar run was made in a freezer held at 0° F.

Cakes occupying positions 1 and 3, as would be expected, showed the fastest cooling rates, and cakes in positions 5 and 8 at the center of the carton were the slowest to cool. The greatest difference in time for the fastest and the slowest cake to cool from 70° F. to 5° F.,[c] for example, in the −20° F. freezer was about 2 hours and 10 minutes. The greatest dif-

[c] No particular significance is intended to be attached to this temperature range. It is merely a compromise selected to illustrate the overall difference between results obtained at the two freezer temperatures without using the obviously impractical final temperature of 0° F. From a purely practical standpoint comparisons at a final product tempereature of 10° F. might be most desirable.

TABLE 5

Times required to warm cakes from 0° F. to 50° F. and to 70° F. (center temperatures) in a cabinet maintained at 80° F. and with about 150 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	0° to 50° F.		0° to 70° F.	
		Hr.	Min.	Hr.	Min.
7-inch layer	Plain, unwrapped	1	43	3	4
7-inch layer	Plain, paperboard box	2	2	3	36
7-inch layer	Butter-cream icing, unwrapped	2	8	4	17
7-inch layer	Butter-cream icing, paperboard box	2	46	5	6
7-inch layer	Fudge icing, unwrapped	1	58	3	45
7-inch layer	Fudge icing, paperboard box	2	22	5	6
9-inch angel food	Unwrapped	1	24	3	0
9-inch angel food	Paperboard box	1	37	3	12
Pound cake	Unwrapped or glassine pan liner	1	13	2	14
Pound cake	Glassine pan liner plus paperboard box	1	48	4	8

TABLE 6

Times required to warm cakes from 0° F. to 50° F. and to 70° F. (center temperatures) in a cabinet maintained at 100° F. and with about 150 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	0° to 50° F.		0° to 70° F.	
		Hr.	Min.	Hr.	Min.
7-inch layer	Plain, unwrapped	0	21	0	42
7-inch layer	Plain, cellophane overwrap	0	22	0	47
7-inch layer	Plain, paperboard box	0	32	0	53
7-inch layer	Butter-cream icing, unwrapped	1	45	2	32
7-inch layer	Butter-cream icing, paperboard box	1	49	2	45
7-inch layer	Fudge icing, unwrapped	1	27	2	8
7-inch layer	Fudge icing, paperboard box	1	43	2	54
8-inch layer	Fudge icing, unwrapped	1	57	2	29
8-inch layer	Fudge icing, paperboard box	2	8	3	13
9-inch angel food	Unwrapped	0	49	1	9
9-inch angel food	Cellophane overwrap	1	2	1	31
9-inch angel food	Paperboard box	1	9	1	38
Pound cake	Unwrapped or glassine pan liner	1	2	1	28
Pound cake	Aluminum foil pan and lid	1	6	1	32
Pound cake	Glassine pan liner plus cellophane overwrap	1	8	1	38
Pound cake	Glassine pan liner plus paperboard box	1	22	2	1

TABLE 7

Times required to warm cakes from 0° F. to 50° F. and to 70° F. (center temperatures) in a cabinet maintained at 120° F. and with about 150 f.p.m. air velocity

Cake type and size	Wrapping or icing conditions	0° to 50° F.		0° to 70° F.	
		Hr.	Min.	Hr.	Min.
9-inch angel food	Unwrapped	0	39	0	57
9-inch angel food	Paperboard box	0	52	1	9
9-inch chiffon	Unwrapped	0	57	1	16
9-inch chiffon	Paperboard box	1	10	1	34
Pound cake	Unwrapped or glassine pan liner	0	37	0	53
Pound cake	Glassine pan liner plus paperboard box	0	59	1	20

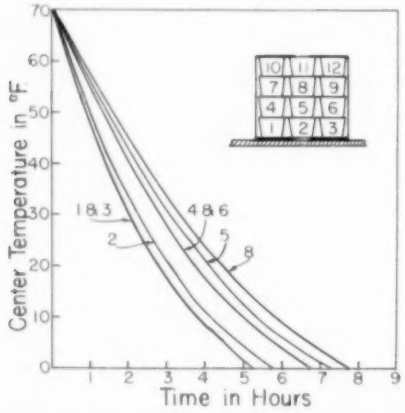

Figure 8. Cooling curves, for pound cakes baked in aluminum foil pans and packed in corrugated cardboard shipping carton in freezer held at −20° F. and with less than 100 f.p.m. air velocity. Inset shows placement of cakes within carton. Numbers identify position of cake and its cooling curve.

ference in time to cool from 70° to 5° F., in the 0° F. freezer was about 3 hours but the overall difference in time between the two freezers was about 4 hours (from about 4½ to 7 hours total compared with about 8 to 11 hours total). Within the cartons themselves there was some graduation in cooling rate from top to bottom. Cakes in positions 1 and 3 cooled at almost identical rates. This was also true of cakes in positions 10 and 12, but the latter pair cooled to 5° F. quite a bit more slowly than the former—approximately 1 hour in the −20° F. freezer and approximately 2 hours and 10 minutes in the 0° F. freezer. Differences between cakes in positions 4 and 6 and positions 7 and 9 were much smaller—only about 10 minutes in the −20° F. freezer and about 30 minutes in the 0° F. freezer. These differences in cooling rates from top to bottom within the cartons probably occurred as a result of development of convection currents at the inside surface of the carton. Air cooled at these surfaces would tend to flow downward to produce lower temperatures at the bottom of the carton.

Effect of rate of freezing or defrosting on quality of cakes. When considering the rates of freezing and defrosting of bakery products, two ultimate factors are of primary importance. Perhaps the more important is the effect variations in freezing or defrosting time may have upon the quality of cakes at the time they are to be eaten. The second pertains to economic factors—the size of installation necessary to freeze a

certain amount of merchandise, the refrigeration capacity required to freeze the merchandise at satisfactory rates, etc. The information presented thus far pertains more to the latter factor, but it all has little value without some information on the first factor.

Cakes have generally been regarded as rather tolerant to variations in freezing and defrosting rates, but little experimental information is available in the literature to verify the conclusion. In the present study, each of the types of cakes used was frozen rapidly (cooled to an internal temperature of 0° F. within 2 hours), slowly (in 10 to 12 hours, for example), or at some intermediate rate, and then subjected to appraisal tests by a taste panel and, in some cases, by physical measurements of firmness. In all the experiments defrosting was accomplished by allowing the frozen, wrapped cakes to stand 4 to 5 hours at room temperature.

With angel food and chiffon cakes, no significant difference in flavor, texture, or firmness could be found as a result of the slow or rapid freezing when the samples were compared with each other or with control portions of the same cakes that had not been frozen. In these experiments the unfrozen control cakes were about 4 hours old and about 24 hours old at the time the comparisons were made. Tables 8 and 9 show the organoleptic results for texture judgments; flavor judgments were almost identical and differences were also non-significant. Average firmness measurements (g. force required for 4 mm. compression) for the 2 types of cake were as follows:

	Angel food	Chiffon
Freshly baked	54.5	55.4
24-hr. old	54.5	41.9
Slowly frozen	57.5	53.4
Intermediately frozen	41.6	51.2
Rapidly frozen	53.7	44.3

No trends are present in these somewhat erratic firmness results and none of the differences are significant, probably because of the small number of readings that could be obtained from the samples available (4 in the case of angel food and 8 for the chiffon cake experiment, which was run twice). Previously reported and more comprehensive results *(10)* show that angel food cakes do not increase significantly in firmness during the first day or two after baking, whether or not they are frozen.

Pound cakes, on the other hand, were detectably influenced by freezing. Cakes that were frozen over a period of 10 to 12 hours, held overnight at 0° F., and defrosted the next day could be reliably differentiated on the basis of texture from freshly baked controls (4 hours after baking) and 24-hour-old controls, but not from cakes frozen rapidly (1 to 2 hours) before being stored overnight. Both frozen cakes were rated significantly less soft in texture than the 4-hour-old controls, but significantly softer in texture than the 24-hour-old controls. The rapidly frozen cakes could not be distinguished from the slowly frozen cakes. These results are illustrated in Tables 10 and 11. Flavor judgments or firmness measurements were not made.

TABLE 8

Taste panel results for texture differences of angel food and chiffon cakes frozen slowly (11.5–13.5 hrs.), at an intermediate rate (4–11 hrs.) or rapidly (1.5–2 hrs.). Samples ranked in order of freshness. For angel food cakes, n = 9 and for chiffon n = 18, where n = number of judgments

	Slow rate of freezing	Intermediate rate of freezing	Rapid rate of freezing
	Angel food cake		
Total score	19	17	18
Mean score[1]	2.11	1.89	2.00
	Chiffon cake		
Total score	38	38	32
Mean score[1]	2.11	2.11	1.77

[1] F value for treatment variances were non-significant (Table 9), mean separation techniques not applicable.

TABLE 9

Analysis of variance for results shown in Table 8

Source of variation	Sum of squares	Degrees of freedom	Mean square	F.
	Angel food cake			
Total	18	27	.....	.....
Treatment	0.22	2	0.11	0.15 n.s.
Residual (error)	17.78	25	0.71	.....
	Chiffon cake			
Total	36	54	.....	.....
Treatment	1.33	2	0.67	1.00 n.s.
Residual (error)	34.67	52	0.67	.....

TABLE 10

Taste panel results for texture differences of pound cake and yellow layer cake frozen slowly (1.5–2 hrs.) or rapidly (10–12 hrs.). Samples were ranked in order of freshness. For pound cakes n = 52 and for yellow layer cakes n = 46, where n = number of judgments

	Fresh control	Slow rate of freezing	Rapid rate of freezing	24-hr.-old control
	Pound cake			
Total score	74	137	119	190
Mean score	1.42	2.63	2.29	3.65
Statistical significance[1]				
	Yellow layer cake			
Total score	97	116	95	152
Mean score	2.11	2.52	2.07	3.31
Statistical significance[1]				

[1] Values not underlined are significantly different from each other at the 5% point.

TABLE 11

Analysis of variance for results shown in Table 10

Source of variation	Sum of squares	Degrees of freedom	Mean square	F.
	Pound cake			
Total	260	156	.....	.....
Treatment	133	3	44.30	53.4**
Residual (error)	127	153	0.83	.....
	Yellow layer cake			
Total	230	138	.....	.....
Treatment	46	3	15.33	11.25**
Residual (error)	184	135	1.36	.....

Results obtained with yellow layer cakes were slightly different in that slowly frozen layers (10 to 12 hours) could not quite be distinguished from either rapidly frozen (1 to 2 hours) layers or from 4-hour old, freshly baked controls. Both the slowly and the rapidly frozen cakes, however, were significantly softer than the 24-hour old controls.

Thus, rate of freezing had no significant effect on organoleptic properties of any of the cakes. Frozen pound cakes, however, were superior to day-old unfrozen cakes but inferior to freshly baked cakes. A point worthy of important emphasis is that freezing in all cases preserved the freshness of cake better than standing only 24 hours at room temperature.

DISCUSSION

With respect to the experimental results a fact of primary importance is that the freezing and defrosting curves and the freezing and defrosting times presented are composites, related closely only to the particular cakes used in this study. The very large variety of shapes, sizes, and kinds of commercial cakes and the wide variation in icings and packages

used commercially make a comprehensive measurement of freezing and defrosting rates prohibitive. A sufficient number of cakes and freezing or defrosting conditions were employed in the present studies, however, to allow commercial operators to make satisfactory estimates of the behavior of cakes of most sizes, shapes, etc. The freezing and defrosting curves obtained in the present study agree reasonably well with the few curves in the literature for cakes of similar size and kind and handled under similar conditions *(2, 6)*.

From a quality standpoint the rates at which cakes freeze or defrost were found to be much less important than for other products, such as bread, but they are not necessarily unimportant. Storage studies currently being completed in this laboratory and to be published in a subsequent article show very definitely that the temperature at which cakes are stored after freezing has an important effect on quality. Thus, although it is true that cakes are relatively tolerant to variations in freezing, defrosting, or storage conditions, best results during storage subsequent to freezing will be obtained only if the freezing is accomplished under the best conditions that can be secured on a practical basis.

SUMMARY AND CONCLUSIONS

Time-temperature relationships for the freezing and defrosting of several types of cake were determined for a range of experimental conditions considered to be representative of commercial practice. Effects of temperature, air velocity, and packaging are presented and discussed for iced and plain layer cakes, angel food, chiffon, and pound cakes.

At both 0° and −20° F., rapid air movement (650 f.p.m. as compared to less than 100 f.p.m.) reduced freezing times of unwrapped cakes to a much greater extent than for wrapped or packaged cakes. Snug cellophane, corrugated glassine, or aluminum foil packaging had less effect on freezing or defrosting rates than typical paperboard cake boxes. Icings on layer cakes prolonged freezing or defrosting times nearly as much as paperboard boxes. Butter-cream icings provided more effective insulation than fudge-type icings. Chiffon cakes froze and defrosted more slowly than angel-food cakes of the same size and under the same conditions. An increase in defrosting temperature from 80° to 100° F. shortened defrosting times by approximately half. A similar increase in defrosting temperature from 100° to 120° F. produced a smaller effect.

Flavor and texture qualities of cakes were apparently unaffected by the difference in freezing times between 1 to 2 hours and 10 to 12 hours. The texture of pound cakes frozen either rapidly or slowly, however, was inferior to that of freshly baked controls. All the frozen cakes were superior to day-old unfrozen cakes.

Acknowledgments

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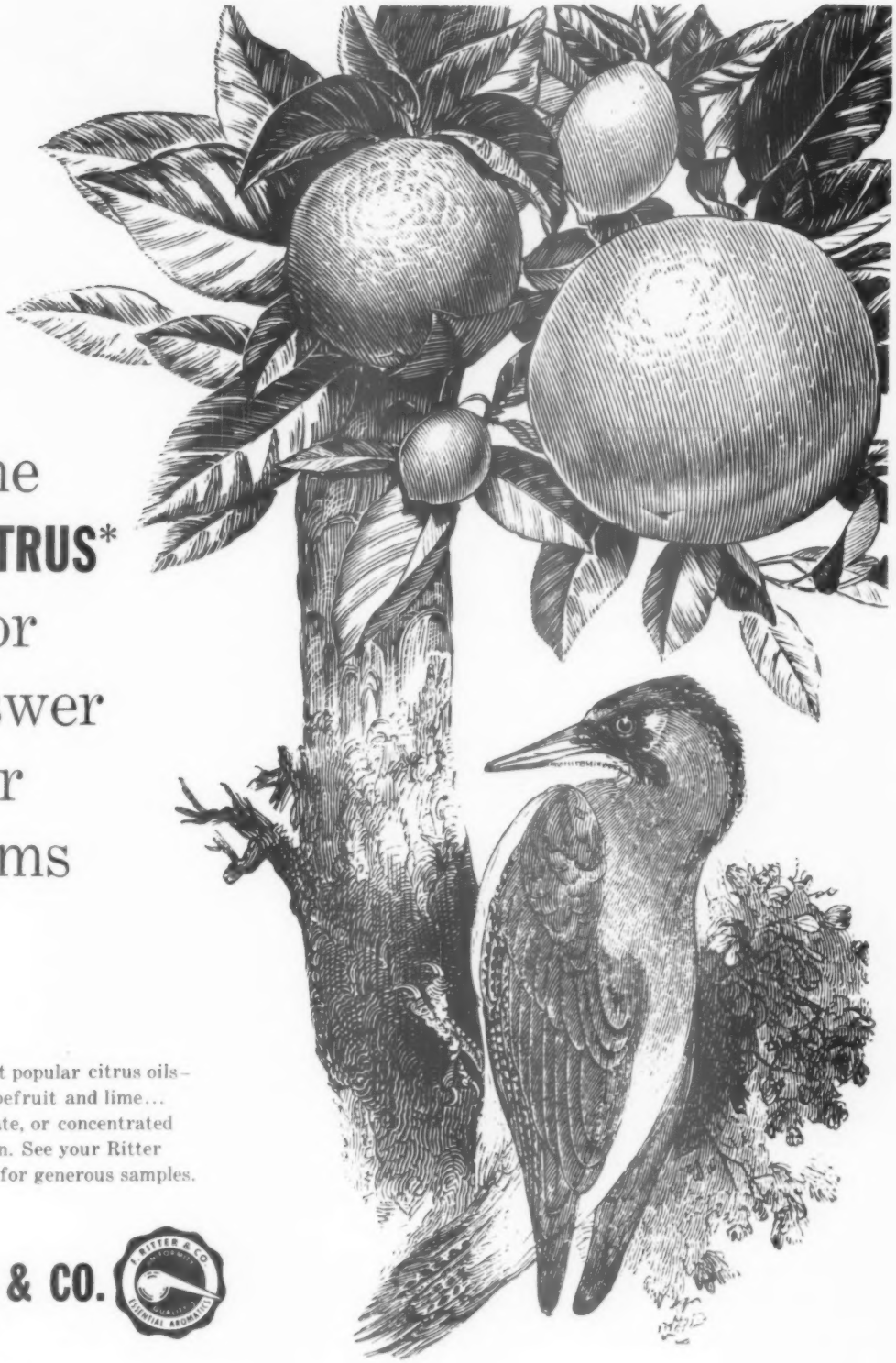

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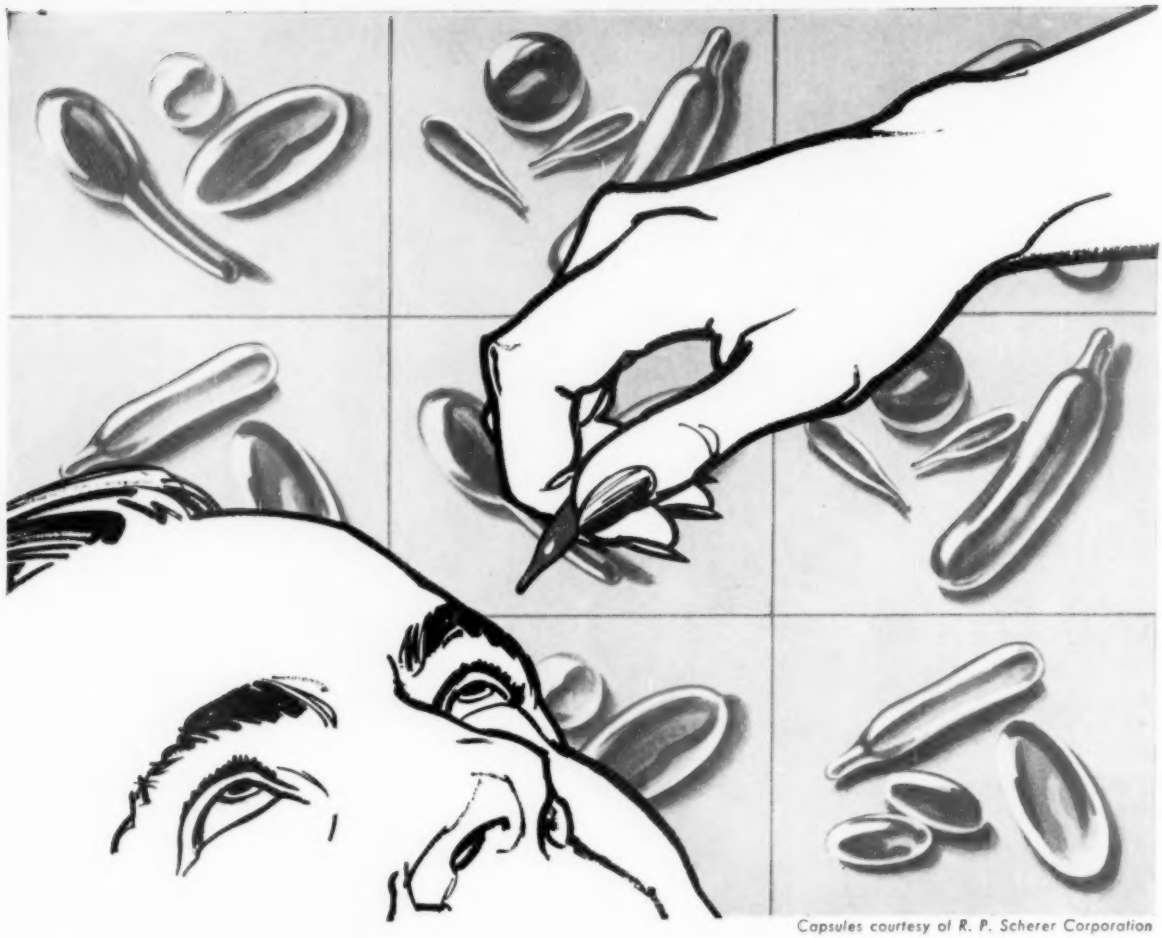

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The Influence of Sugar in Ice Cream. II.

Consumer Preferences for Strawberry Ice Cream

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(Manuscript received July 11, 1958)

In studies made years ago, when refrigeration was inadequate and the batch freezer was the backbone of the dairy industry, a sugar level of 15% came to be accepted by the industry as being satisfactory for most people. A recent investigation *(3)* showed that a large consumer panel preferred vanilla ice cream containing 15, 17, or 19% sucrose equally well, and to a significant degree over samples containing 13 or 11% sucrose. At the present time, the dairy industry does not alter the sugar content of ice cream appreciably when other changes in composition, such as butterfat or milk solids, are made. Seldom is the sugar level adjusted for different flavors except for the sugar in the flavoring material itself. One mix of standard composition is used and different flavoring ingredients are added to produce the desired flavors.

In the investigation described herein, strawberry ice cream was packed with various sugar levels then evaluated by a household consumer panel as well as by a trained laboratory taste panel.

METHODS AND MATERIALS

Raw material. Processing procedures employed were similar to those normally followed in commercial operations. The unflavored mixes tested 12% butterfat, 11% solids-not-fat, 0.3% stabilizer, and sucrose levels of 15, 17, 19, or 21%. After pasteurization at 165° F. for 30 min., the mix was homogenized at 25,000 p.s.i. and 500 p.s.i., cooled and stored overnight. Frozen strawberries (4 plus 1), commonly used as a flavoring source by ice cream manufacturers, were thawed then puréed to assure uniform flavoring in all samples of ice cream. Sufficient berries were added to give an equivalent of 15% berries in the flavored mix; 18.15 lbs. of the 4 plus 1 (fruit to sucrose) strawberries to 81.25 lbs. unflavored mix. To give a more definite pink color to the product, 7 ml. of red coloring per gal. mix was added. Total sugar content, including the added sucrose and the sweetened berries, was 15.9, 17.6, 19.2, or 20.8%.

Consumer survey. Letters of solicitation for participation were mailed to 400 families selected at random from the telephone directory of Woodland, California (pop. 12,000). Of the 400 families selected, 210 agreed to participate, of which a total of 203 families returned their completed score cards. Non-participation was attributed to families who had moved, were on vacation, did not like strawberry ice cream, or were not interested.

Two pints of strawberry ice cream coded "X-6" and "W-7", a detailed instruction sheet and score cards were delivered to each participating household in September, 1957. The homemaker was directed to place the samples in the freezer part of her refrigerator immediately, and to serve the ice cream at a regular family meal within the next 2 days. Each family member over 6 years of age completed an individual score card asking for age, sex, the meal at which the ice cream was tasted, and his preference. If the taster had a reason for his preference, he indicated such on the reverse side of the score card. In addition to the individual cards, the homemaker was asked to complete a questionnaire regarding her family's frequency of consumption of ice cream in general and of strawberry ice cream in particular. A hypothetical price differential was established between the 2 pints of ice cream and the homemaker indicated which of the samples she would purchase if: (1) "X-6" cost 5¢ per pint more than "W-7"; (2) "W-7" cost 5¢ per pint more than "X-6"; (3) both samples cost the same. Upon completion of the sampling, the score cards and questionnaire were returned to the survey director in a stamped, addressed envelope provided for the purpose.

The 6 possible paired combinations, as well as the reverse orders, were distributed randomly among the participating families. Resulting preferences (excluding "no preference" responses) were analyzed statistically, using the method of chi-square *(4)* for paired comparisons and the arc sine transformation method *(1)* for over-all significance.

RESULTS AND DISCUSSION

A total of 326 males and 324 females participated in the survey (Table 1). Classification of preferences by the tasters' age and sex (Table 2) indicated a greater liking for Sample C (19.2% sugar) than for the other samples. No differences in preferences between the sexes were observed, but slight preference variations existed between age groups.

TABLE 1

Participants on strawberry ice cream consumer survey[1]

Age	Male	Female	Total
Under 16	87	83	170
16–24	26	29	55
25–39	85	91	176
40–59	104	90	194
Over 60	24	31	55
Totals	326	325	650

[1] Number of families participating, 203.

TABLE 2

Preferences for strawberry ice cream classified by age and sex (Percent comparative preference)[1]

Age and sex group	Sugar levels			
	15.9% A	17.6% B	19.2% C	20.8% D
Age				
Under 16	18.5	20.9	*33.5*	27.1
16–24	22.7	17.3	26.4	*33.6*
25–39	18.2	23.3	*34.1*	24.4
40–59	*26.8*	20.6	26.3	26.3
Over 60	24.5	*28.2*	24.5	22.8
Sex				
Male	20.4	24.4	*29.1*	26.1
Female	23.1	19.8	*30.6*	26.5
Total	21.8	22.1	*29.8*	26.3

[1] Italicized values indicate samples receiving the greatest number of total preferences.

TABLE 3

Over-all preferences for strawberry ice cream[1]

Pairs[2]	Consumer panel			Laboratory panel		
			NP[3]			
A vs. B	A 57	B 46	18	A 12	B 28*	2
A vs. C	A 30	C 56**	15	A 15	C 20	1
A vs. D	A 33	D 52	10	A 25	D 17	1
B vs. C	B 38	C 57	9	B 15	C 15	4
B vs. D	B 38	D 53	16	B 11	D 13	4
C vs. D	C 62	D 46	14	C 23	D 12	2
Total comparative preferences	A 120	B 122	C 175	D 151	NP 82	A 52	B 54	C 58	D 42	NP 14

[1] Values represent number of individuals.
[2] Sample Codes A = 15.9%; B = 17.6%; C = 19.2%; D = 20.8% sugar.
[3] No preference.
[*] Significant preference at the 5% level of probability.
[**] Significant preference at the 1% level of probability.

Total preferences expressed by the consumer panel and by the laboratory taste panel are presented in Table 3. Sample C was preferred by the consumers to a significant degree over Samples A and B, and to a lesser degree over Sample D. Whereas the consumers liked Sample D second best, it was the least liked by the laboratory panel. The latter panel exhibited a significant choice in only one paired comparison, where B was preferred over A. Of the total number of individuals participating, 12.8% of the consumers and 6.4% of the laboratory tasters gave a "no preference" response.

In order to determine whether significant differences existed between total preferences, the percent preferences were converted into a form in which they would be independent of the variances using the conversion formula:

$$X = \text{arc sin } \sqrt{\text{percentage}} \quad (1)$$

The analysis of variance performed on these X values is given in Table 4. Treatment differences were significant at the 5% level of probability. The L.S.D. value of 3.31 shows that Samples C and D were equally well liked and were significantly preferred over less sweet ice cream.

TABLE 4

Statistical treatment of consumer preferences for strawberry ice cream

(Analysis of variance based on values of Arc Sin $\sqrt{P}$)

Source	Sums of squares	Degrees of freedom	Mean square	F ratio
Total	307.76	11		
Treatment	187.53	3	62.51	4.16*
Error	120.23	8	15.03	

[*] Significant difference at the 5% level of probability.

Least Significant Difference Between Treatment Means

Sample	A	B	C	D
Mean (Arc Sin $\sqrt{P}$)	41.44	41.05	50.50	47.00

$$\text{L.S.D.} = t_{.05} \times \sqrt{\frac{2(15.03)}{3}} = 3.21$$
$$(6\ df.)$$

Reasons most frequently given for preferring the sweeter samples were (a) more flavorful, (b) richer, (c) creamier. Of the total consumer population, only 8 individuals remarked that one of the samples was too sweet.

Over 75% of the families interviewed stated they consumed ice cream with a frequency of more than once a week (Table 5). Apparently strawberry-flavored ice cream is not purchased as frequently as are other ice creams. Several homemakers remarked that if the experimental samples were available commercially, more strawberry-flavored ice cream would be consumed in their households. Five families reported they never purchased strawberry ice cream yet indicated a liking for the experimental pack.

TABLE 5

Frequency of consumption of ice cream in general and strawberry ice cream in particular

Frequency	Total consumption		Strawberry ice cream consumption	
	Number families	%	Number families	%
More than once/week	151	75.1	21	10.3
More than once/month	49	24.4	91	44.8
More than once/year	1	0.5	86	42.4
Never	0	0.0	5	2.5
Totals	201[1]	100	203	100

[1] Two families failed to answer this question.

TABLE 6

Influence of 5¢/pint price differential on indicated buying behavior

(Number of families responding)

Question 1. If FIRST sample cost 5¢/pint more, which would you buy?

A	B	A	C	A	D	B	C	B	D	C	D
18	17	14	17	13	19	12	17	16	13	19	16

Question 2. If SECOND sample cost 5¢/pint more, which would you buy?

A	B	A	C	A	D	B	C	B	D	C	D
19	16	12	16	9	23	15	14	15	14	19	14

Question 3. If BOTH samples cost the same, which would you buy?

A	B	A	C	A	D	B	C	B	D	C	D
20	16	15	17	11	21	13	15	13	15	23	12

The technique applied to gauge the homemaker's reaction to price was modeled after that used by The Kroger Food Foundation *(2)*. Table 6 summarizes the responses which sugest that a difference of 5¢ per pint would not keep the homemaker from purchasing the ice cream her family preferred. Few variations in preferences were observed when the hypothetical price difference was stipulated, as can be seen by comparing the responses to the first two questions with the response to question 3.

SUMMARY

Strawberry ice cream varying in sugar content (15.9%, 17.6%, 19.2%, or 20.8%) was evaluated by

650 individuals in a household consumer survey employing the method of paired comparison-preference. Both the consumer panel and a trained laboratory panel preferred the sample containing 19.2% sugar to a significant degree over the other samples. Reasons most frequently given for preferring the sweeter samples were (a) more flavorful, (b) richer, (c) creamier. The majority of the homemakers interviewed indicated that they were willing to pay 5¢ per pint extra for the sample their family preferred. If adjusting the sugar content of ice cream results in a more flavorful product that the majority of the consumers like and are willing to pay extra for, then a reappraisal of the sweetness levels used in the ice cream industry seems to be in order.

Acknowledgments

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Ultrasonic Defrosting of Frozen Foods

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(Manuscript received August 1, 1958)

Fast thawing of frozen foods is desirable because it retards bacterial buildup and loss of color and flavor, and because of convenience. Present domestic and commercial practice defrosts frozen foods by static or moving fluids such as air or water *(1, 8)*. Rate of thawing, however, even under optimum conditions, is relatively slow because of the low rate of heat transfer between the thawing medium and the interior of the food mass. This heat-transfer rate is limited by the maximum temperature which the outer portions of the food can withstand without beginning to cook.

An ideal method of thawing would be to supply a form of energy which would be absorbed rapidly and uniformly throughout a food mass. Electromagnetic radiation has been considered for uniform food thawing. Many investigations have been reported on the application of electromagnetic radiations in the infrared *(7)* and microwave *(2, 3, 6)* region. Because of low penetration, infrared tends to cook surfaces before interior thawing occurs. Experiments with microwaves showed that selective absorption by the liquid constituents of foods results in the cooking of these constituents before the bulk of the food is thawed. Heat generation in materials through the absorption of ultrasonic energy is a well-known phenomenon. It has been experimentally used for cooking and is being used for therapeutic purposes *(4)*. Internal liquefaction of pure ice by heat dissipation caused by reflection and scattering of ultrasonic waves at some discontinuity in the ice mass has also been reported *(4)*. Since frozen foods are generally heterogeneous, both in matter and in crystalline structure, they would appear to be good absorbers of ultrasonic energy; hence, ultrasonic vibrations were considered as a possible source of energy for rapid thawing.

Although both literature and patent searches revealed many references to thawing frozen food, no reference was found on the application of ultrasonic energy to this problem *(5)*. The following investigation was conducted to determine ultrasonic absorption characteristics of representative frozen foods and feasibility of defrosting frozen foods with ultrasonic waves.

EXPERIMENTAL METHODS

Equipment. Four vibration frequencies representative of the practical ultrasonic and high sonic spectrum were used to study the influences of vibratory energy on the thawing rate of frozen foods. Figure 1 shows a unit used to investigate food thawing characteristics at 400 and 1000 kc. A cylindrical stainless steel food chamber 1¾ x 4 in. sealed at the bottom with an 0.0025 in. diaphragm was inserted in a water-cooling coil which was in turn mounted in a focussed-bowl $BaTiO_3$ transducer[a] assembly. Water was used to couple the transducer to the chamber. The focal point of the transducer was approximately 1 in. above the diaphragm on the vertical axis of the container.

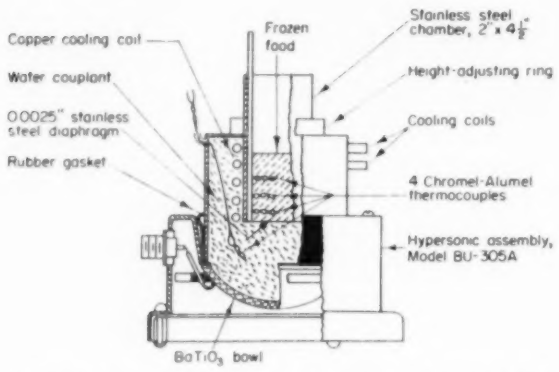

Figure 1. Assembly for thawing frozen food samples with 400 kc and 1000 kc vibrations.

A similar arrangement was used for the 20 kc studies, except that a 2400-watt nickel transducer, driving a double cylinder mechanical transformer was used to generate vibrations in the food chamber. Water was again the couplant.[b]

Investigations at 10 kc were made with a nickel transducer assembly directly coupled to the diaphragm of a water-cooled 1⅞ x 3⅞ in. cylindrical chamber.

Power supplied to the 400 and 1000 kc transducers was metered during thawing. Power supplied to the 10 and 20 kc transducers was estimated from their ratings and operating characteristics. Power inputs were maintained as nearly as possible at 100 watts except for the 20 kc unit which was supplied with higher power.

Food samples. Frozen hamburger, strawberries, and liquid whole eggs were selected as representative frozen foods for the thawing experiments. Samples were prepared by placing them in the food chamber to a depth of 2 inches and freezing.

Temperature readings. Chromel-alumel thermocouples were located along the central axis of the food container prior to freezing to determine temperature variations. In the 1¾ x 2 in. samples, thermocouples were located ¼ in., ¾ in., and 1¼ in. above the diaphragm and in the couplant or cooling water. Thermocouple readings were made at one minute intervals until samples were completely thawed. No attempt was made to maintain couplant temperature constant except in the case of the 10 kc assembly. Therefore, transducer heating and couplant losses, as well as ultrasonic effects, contributed to thawing. This was done to ascertain the relative merit of using to the fullest the power supplied by the transducers.

[a] A transducer converts electrical energy from the line into vibratory or acoustical energy, i.e., electrical energy is the input to a $BaTiO_3$ transducer, and sonic vibrations are its output.

[b] An intermediary link between transducer and product was used because of the impedance mismatch between transducer output and food. The water couplant acted as a transformer which improved the matching.

RESULTS AND DISCUSSION

Hamburger. Hamburger frozen to −100° F. was thawed with each of the 4 transducer arrangements. Figure 2 shows curves of temperatures measured at various points of the sample during thawing. Complete thaw was assumed to have occurred when the last thermocouple to reach 32° F. began to show a temperature increase. Control hamburger required more than 60 minutes to thaw.

Effectiveness of vibratory energy in thawing ground beef appeared to be frequency dependent. The lower frequencies had little or no effect on thawing rate, but higher frequencies produced more rapid thawing than natural thaw, 1000 kc thawing being faster than 400 kc thawing. There was a rapid temperature rise once the meat reached thawing temperature, indicating selective energy absorption by thawed meat. Examination of samples heated after thawing showed a ¼-in. layer of cooked meat near the bottom. This relatively uniform layer indicated that, despite a focussed sound field, a relatively uniform field distribution was obtained in the meat, possibly because of refraction and dispersion of the sound beam in the heterogeneous meat structure. In one instance, an extremely rapid temperature rise at a thermo-

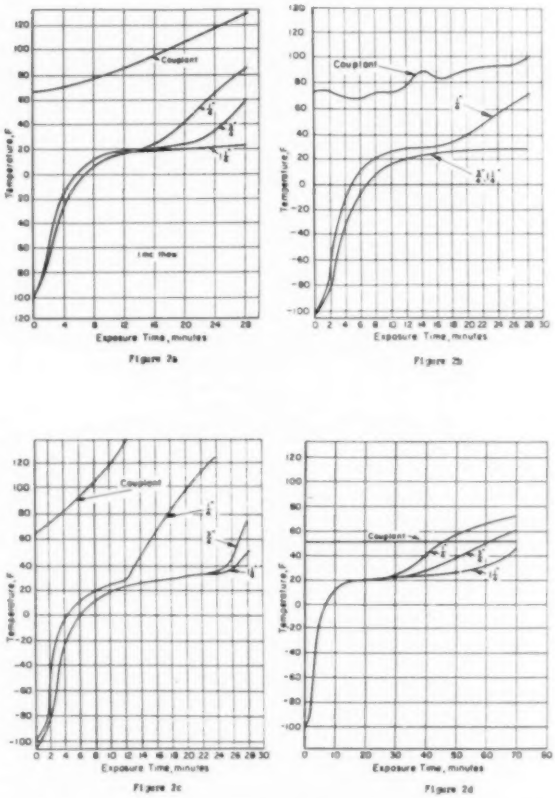

Figure 2. Time-temperature relationships at various points in samples of chopped beef thawed with ultrasonic energy. Temperatures were measured in sample at indicated distances from surface exposed to vibration. a) 1000 kc, 100 watts; b) 400 kc, 100 watts; c) 20 kc, 1000 watts; d) 10 kc, 100 watts.

couple was found to be due to selective energy absorption by a fat particle surrounding the couple.

The difference in impedance between couplant and hamburger may account for some of the temperature rise of the coupling water. Calculations show that from 30 to 40% of the incident ultrasonic energy is reflected from a water-ice interface. At a water-frozen meat interface, the reflectance could be larger.

Reflection from frozen meat back to the transducer was observed during studies with the 400 kc transducer. The silver plated surface at the transducer was partially eroded by cavitation directly below the sample chamber. This could account for the temperature rise in the water couplant. However, the predominant cause of couplant temperature rise was more likely the electrical loss in the transducer.

Temperature variations within a hamburger sample during thawing showed that thawing was not due to uniform internal absorption of vibrations, but rather to absorption at the meat surface normal to the incident energy, and to heat conduction from couplant or thawed meat to the frozen meat.

Strawberries. Commercially prepared sliced strawberries, with thermocouples imbedded in berries, were used to study the effects of vibratory energy on thawing foods preserved in liquids. Figure 3 shows curves

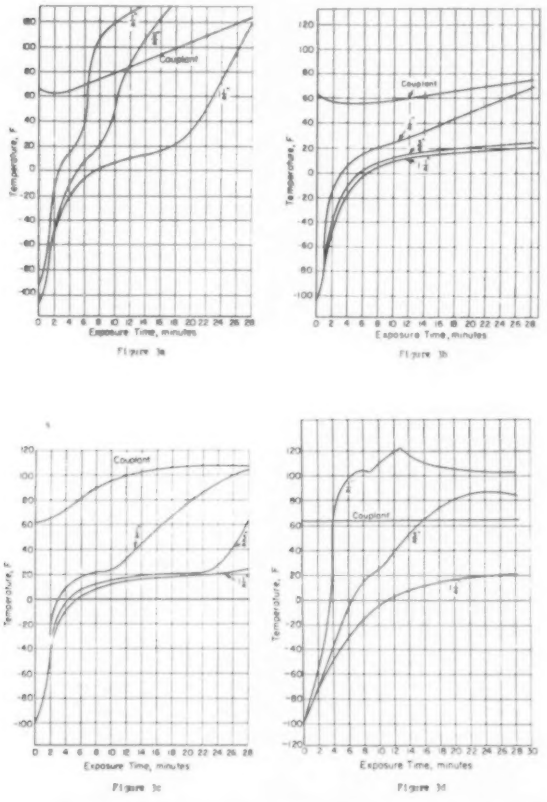

Figure 3. Time-temperature relationships at various points in samples of strawberries thawed with ultrasonic energy. Temperatures were measured in sample at indicated distances from surface exposed to vibration. a) 1000 kc, 100 watts; b) 400 kc, 100 watts; c) 20 kc, 1000 watts; d) 10 kc, 100 watts.

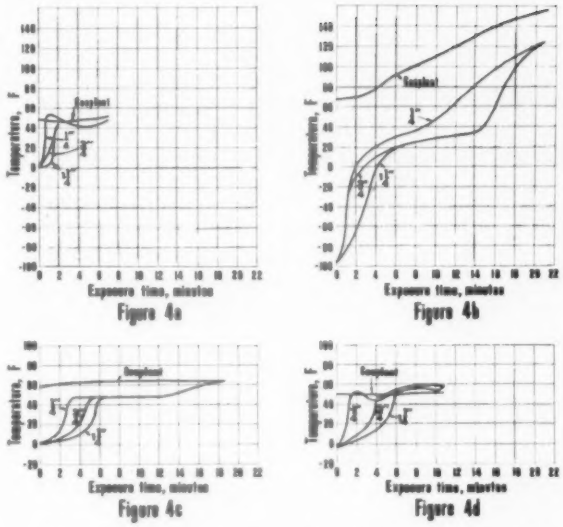

Figure 4. Time-temperature relationships at various points in samples of frozen liquid whole eggs thawed with ultrasonic energy. Temperatures were measured in sample at indicated distances from surface exposed to vibration. a) 1000 kc, 100 watts; b) 20 kc, 1000 watts; c) 400 kc, 100 watts; d) 10 kc, 100 watts.

of temperature variation with time under various thawing conditions. Control strawberries required 70 minutes to thaw.

Rate of thawing was increased by ultrasonic energy. Rapid thawing observed at the first thermocouple location indicated high absorption by the sample. In 1000 kc and 400 kc thawing, couplant temperature did not begin to rise until the first thermocouple showed complete thaw. However, temperature variations between thermocouples indicated that thawing was not uniform.

Thawing at 10 kc appeared most effective, possibly because of mass berry agitation and forced circulation of the sirup rather than from direct absorption of vibratory energy with berries. At frequencies above 15 kc, radiation wavelength would be shorter than berry dimensions, resulting in scattering of incident energy which is dissipated as heat around the berry. At low frequencies, wavelengths greater than berry dimensions could result in mass agitation. This would cause a more rapid heat transfer between berry and sirup. Agitation is also expected at higher frequencies because of hydrostatic forces developed by focussed fields. At the relatively low power levels used, however, when the sirup thaws, berries tend to settle on the diaphragm, dispersing the focussed field and reducing hydrostatic forces. Discontinuities in the temperature curve of thermocouple nearest the chamber diaphragm indicated berry agitation at 10 kc.

Eggs. Frozen liquid whole egg was used to study the effect of ultrasonic vibrations on thawing of liquid products. Figure 4 shows temperature measurement during egg thawing. Control eggs required 76 minutes to thaw.

Ultrasonic energy absorption was indicated by the rapid rise in sample temperature and the relatively constant couplant temperature until sample thaw points were reached. Impedance mismatch between couplant and frozen sample should result in energy reflection. Since this was not evidenced as a couplant temperature rise, another ultrasonic effect, streaming, may have occurred with molecular absorption in the mass. Because of mismatch between solid and liquid sample phases, heating was produced initially by reflection and beam scattering. This resulted in rapid thawing at the chamber-egg interface. High ultrasonic absorption of liquid egg then took place. Hydrostatic forces in the liquid sample from factors such as non-uniform field distribution and viscous drag caused streaming and continuous mixing of thawed sample. This would account for temperature peaking in 1000 kc and 10 kc thawing, and also for apparently higher temperatures at complete thaw for ultrasonic thawing.

Streaming was apparent in all egg samples exposed to vibrations when they were completely thawed by surface agitation. It was most pronounced at 1000 kc. Temperature discontinuities were attributed to cracks in frozen sample which propagated about couples during thawing.

CONCLUSIONS

Ultrasonic waves incident upon frozen food first thaws the surface of the food by reflection and dispersion at the interface of food and source of sound wave. Since thawed material absorbs more energy than frozen food, heat is generated in thawed material. Also, since the thermal conductivity of food is low, excessive local heating results while the bulk of food is frozen. This was found to occur with hamburger, and expected to occur in other meats, fish, and vegetables.

In the case of foods frozen in a liquid, thawing is due to heat conduction from the liquid-food interface. Relatively rapid thawing can be expected because microagitation increases the rate of heat transfer from liquid to solid. However, if individual pieces of frozen food are large or are tightly packed, excessive local heating can occur before the food is completely thawed.

Liquid foods, such as eggs and juices, thaw rapidly when exposed to ultrasonic vibrations. The liquid phase absorbs most of the energy and, by streaming or convection currents, transfers heat to the frozen phase. In viscous foods, excessive local heating can occur before the food is completely thawed.

Coupling between the ultrasonic source and the food is a factor governing the energy required for thawing. Direct contact between food and energy source would be most desirable but, in the case of crystal-type transducers, temperature gradients during thawing would fracture the crystals. Irregular shapes of foods make direct coupling methods impractical. A liquid couplant such as water would be required. However, water has a low cavitation threshold which could lead to energy dispersion within the couplant rather than in the food. If water were degassed and subjected to high pressures along with the food, the cavitation threshold can be raised.

The relatively high energy requirements to achieve reasonable thawing rates in liquid foods and negligible effects in solid foods indicate inherent limitations of ultrasonic thawing. Thus, the use of ultrasonic energy to defrost frozen foods does not appear to be feasible because:

1) absorption characteristics of frozen foods are such that internal heating is difficult to realize;

2) there seems to be no practical means of coupling ultrasonic energy effectively to various types of food at present; and

3) observed ultrasonic thawing rates do not appear to be sufficiently above conventional thawing rates to justify expenditure of approximately $1,000 per kilowatt, present cost of commercially manufactured ultrasonic equipment.

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Orange Juice Powder.

Factors Affecting Storage Stability

(Manuscript received April 25, 1958)

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PUFF DRYING TECHNIQUES reported by Strashun and Talburt *(20)* have been applied to several fruit and vegetable juices *(6, 13, 14)*. The products all have good quality when produced but may suffer during storage as evidenced by changes in flavor, color, and ascorbic acid. Caking and shrinking may also reduce their marketability.

Several advances have been described since Strashun and Talburt first reported the puff drying of orange juice powder. Mylne and Seamans *(11)* reported the availability of a paper-envelope desiccant container to replace the pill-box type. Schultz *et al. (17)* published work on the use of sugars as carriers for citrus oil. The commercial production of citrus powders *(2)* and the use of cans larger than 6 ounces have focused attention on the in-package desiccation and caking problem.

Mylne and Seamans *(11)* reported on the storage stability of orange-juice powder containing 40% corn syrup solids. Experiments with this powder evaluated a number of variables for gross effects. In the studies reported here the variables were container size; can atmosphere and pessure; location and type of desiccant; extended drying time; temperature for conditioning (lowering of moisture content of the powder from "as received" to 1%); storage temperatures and times; citrus oil content in the powder and carrier; type of carrier; sulfur dioxide and corn sirup solids as additives; and related factors.

ANALYTICAL METHODS

A puncture-type canners' gauge was used for routine vacuum determinations. Moisture of powder was determined by vacuum-oven method (60° C., 0.6 mm. Hg, 30 hours) *(11)* and modified Karl Fischer method *(9)*. Brix was determined refractometrically. Suspended pulp was determined on 12° Brix material by centrifuging (10 minutes, 1,270 r.p.m., 16 in. diameter) *(25)*. Ascorbic acid was determined by the Loeffler and Ponting method *(7)*, and reductones were assayed by the method of Wokes *et al., (23)*. Sulfur dioxide was determined by a modification of the Monier-Williams method *(10)*. Reducing sugars were determined by AOAC Munson-Walker general method *(1)*. Cloud values were ascertained in a 1 cm. cell with a 640–700 mμ filter (Senn *et al.) (18)*. Color was determined as the Klett colorimeter reading of the clarified extract from a 5% aqueous solution of the powder in a 4-cm. cell with a 400–645 mμ filter *(13, 14)*. Pectinesterase was determined on feed and powder by the method of MacDonell, Jansen, and Lineweaver *(8)*. Moisture equilibria of powders were determined by the method of Wink *(22)*, using sulfuric acid solutions for relative humidities below 11% *(12)*. Recoverable oil was determined by a modified McKinnes apparatus as described by Curl *(3)*. Sticky point was noted as that temperature at which severe resistance to turning is encountered by a metal propeller embedded in a powder sample. The sample is contained in a mercury sealed test tube immersed in a water bath, the temperature of which can be raised about 0.1 to 0.2° C. per minute. Particle size was determined by sieving for 5 minutes on U. S. standard sieve screens. Relative apparent viscosity of the reconstituted juice was determined by measuring its drainage time from a pipette at 23° C. and comparing it to the drainage time of distilled water under the same conditions. A material was considered caked when a sharp rap of its container on a wooden surface failed to render the material particulate.

RAW MATERIALS

Frozen unsweetened Valencia orange juice concentrate containing 61% soluble solids and 63.4% total solids was used as the feed material. The concentrate had not been heated to inactivate the enzymes. Pulp strained and squeezed dry from single-strength juice was added to make 9% by volume on a 12° Brix basis *(25)*. Sulfur dioxide was added as $NaHSO_3$ (0.2 g. per pound of soluble solids). The corn-sirup-containing powders were prepared with 24 DE (Dextrose Equivalent) corn sirup solids *(11)*. One sample of feed was fortified with cold-pressed peel oil to about twice the original oil content. Composition of feed and resultant powder are given in Table 1.

TABLE 1

Composition of Valencia orange juice concentrate and powder

	Feed, MFB[1]	Powder, MFB
Ascorbic acid	325 mg./100	312 mg./100
Total sugar (as glucose)	78.0%	80.0%
Reducing sugars (as glucose)	32.2%	33.0%
Acidity as citric acid	6.9%	7.0%
Volatile oil	0.064%	0.058%
SO_2	183 p.p.m.	149 p.p.m.

[1] Moisture-free basis.

EXPLORATORY EXPERIMENTS

A preliminary test indicated that some protection of flavor was exerted by 10% of corn sirup solids (CSS) and still more by 20%. Amounts in excess of 20% contributed but slightly to storage stability. The powder used in this test was produced from sulfited concentrate, was vacuum packed with in-package desiccant (IPD), and stored 6 months at 100° F. Results of the taste evaluation are presented in Table 2. Sulfur dioxide analyses of the samples after storage varied from 140 to 183 p.p.m. and did not correlate with the flavor scores. These data also indicate that CSS were the major protective influence on flavor in this experiment. Also, the CSS did not serve to hold the sulfur dioxide in the powder.

The effect of extended drying was determined by placing screened (6-mesh) powder containing 3% moisture on trays at 0.3, 0.6, and 1.2 pound per square foot and drying at 100° F. for 72 hours at 0.5 mm. Hg pressure. The final moisture content of all samples was 1.3%. A similar powder sample packaged in a 6-oz. can (IPD, vacuum), stored 72 hours at 100° F. had a final moisture content of 1.3%, thus indicating that the rate-controlling variable in desiccation is the vapor releasing mechanism.

Sorbitol-entrapped oil, used for flavoring the powders, was prepared by the method of Griffin *(5)*, and sucrose and dex-

[a] Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

TABLE 2

Effect of corn sirup solids (CSS) on stability of orange juice powder stored for 6 months

Average palatability scores[1]

Added corn sirup solids, per cent, moisture-free basis	Storage temperature	
	−30° F.	100° F.
40	9.0	7.4
30	9.0	6.6
20	9.0	6.0
10	9.0	5.8
0	9.0	4.6

[1] Scored on a scale of 1 to 10. The higher the number, the better the quality. A score of 6 was considered to be the limit of acceptability.

TABLE 3

Effect of piece size on retention of oil in carrier

Piece size	Volatile oil content, %[1]	
	Original	After evacuation[2]
2 cm. x 2 cm. x 2 mm.	7.2	7.2
−10 + 20 mesh	5.2	4.1
−20 + 40 mesh	3.6	2.9
−40 + 60 mesh	3.2	1.7

[1] Volume by weight.
[2] Evacuated 3 days at 0.2 mm. Hg., 23° C.

trose-entrapped oil by the method of Schultz *et al. (17)*. The granules containing oil were evacuated for 3 days at 0.2 mm. Hg and 23° C. (73.4° F.). This treatment removes orange oil from the surface of the granules. Oil on surfaces deteriorates and results in flavors described as "terpene" or "paint-like." Granules containing entrapped oil were −10+20 mesh. This size provides fairly rapid solubility with good oil retention. The effect of granule size on oil retention is shown in Table 3 *(4)*. Carrier-entrapped oil pieces 2 cm.^{2} x 2 mm. have maintained their flavor quality unimpaired after 18 months at 100° F. Oil analyses of samples taken from a No. 10 can of powder revealed that the oil-in-carrier was distributed so uniformly that no sample varied more than 6% from the average (0.098%). Thus, consumers are assured that the large-sized package contains uniformly distributed flavor.

PREPARATION OF POWDER

The powder was produced by puff drying under conditions described by Strashun and Talburt *(20)*: 2 mm. Hg pressure, 140° F. maximum product temperature, tray loading one-half pound per square foot, total time in the drier 2 hours. The dried puffed material was passed through a 6-mesh screen. All handling of the dried material was done in a low (below 10% RH) humidity room. Moisture equilibrium data are shown in Figure 1.

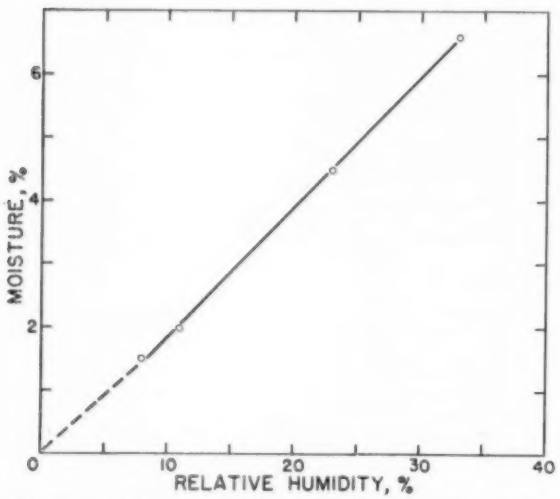

Figure 1. Moisture equilibrium orange juice powder, 70° F.

Flavoring components lost during concentration and puff drying were replaced by cold-pressed peel oil entrapped in solid carriers. The residual oil in the powder (90% of the original) was ignored because of its low flavoring potency.

PACKAGING

The powder (3.0% moisture) was packed in 202 x 314 cans (6-oz.), 75 g. of powder per can, with sufficient entrapped oil to yield a single-strength (12° Brix) juice containing 0.0065% added oil. The desiccant, inserted in the can during packaging, was 10 g. of calcined lime (CaO) in a heat-sealed, moisture-permeable, siftproof envelope *(21)*. The desiccant had sufficient capacity to absorb 25% more moisture than was present in the powder. Cans were vacuum packed at about 29 in. Hg.

Powder was packed also in beaded 603 x 700 (No. 10) cans containing 1.05 kg. of powder (2.8% moisture), 140 g. of calcined lime desiccant (enveloped as mentioned above), and entrapped oil. The cans were packed with 15 in. Hg vacuum. Location of the desiccant in the cans was varied to include longitudinal center, longitudinal side, and transverse end.

POWDER CHARACTERISTICS

Microscopic examination of the powder showed the average wall thickness of the material forming bubbles to be 0.026 mm. (varying from 0.007 to 0.6 mm.). The bubble diameter varied from 0.03 to 0.7 mm. The density of the powder as determined by toluene displacement was 1.8 g. per ml. The void volume was 71%. Particle size distribution is given in Table 4, as well as moisture content and bulk density for the size classes.

TABLE 4

Properties of sieved[1] orange juice powder

Size class mesh/inch	Retained	Moisture	Loose	Compacted
	%	%	g./ml.	g./ml.
−10 + 16	25	3.2	0.26	0.31
−16 + 20	4	3.3	0.32	0.37
−20 + 40	31	3.2	0.40	0.47
−40 + 60	18	2.9	0.47	0.55
−60	22	2.4	0.55	0.71
Not sieved		2.9	0.36	0.45

[1] Powder sieved 5 minutes on U. S. Standard sieve screens mounted on a Cenco-Meinzer Sieve Shaker.

Schroeder and Cotton *(16)* presented data indicating that the moisture content of puffed orange juice varied from 0.9% on the heated surface to 1.8% one inch from the heated surface. Recognizing that the drier material is more fragile, it is not surprising that the smaller particles have a lower moisture content.

The sticky point of the powder and caking tendency are moisture-dependent phenomena. Sticky point is the instantaneous caking temperature. The effect of moisture content on sticky-point temperature is shown in Figure 2. The product must be cooled below the sticky-point temperature in order to remove it from the drying surface and screen it satisfactorily.

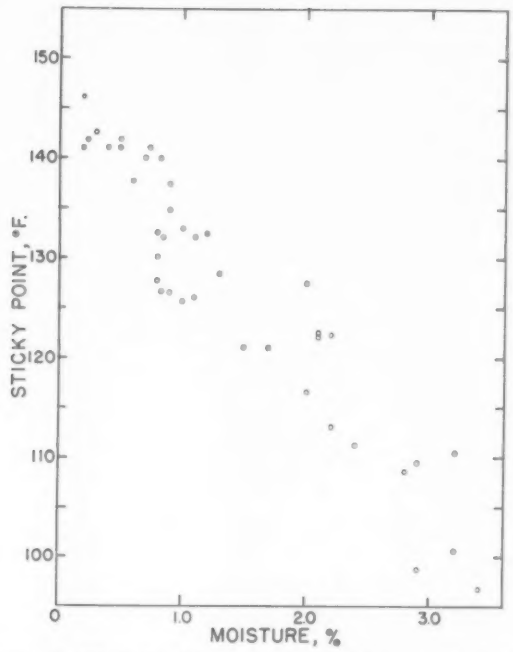

Figure 2. Effect of moisture content of powder on sticky point.

DESICCATION RATE

Samples packed in 6-oz. cans were held at 77° F. for 78 days to lower the moisture content from 3.0% to 1.0%. Vacuum-oven and Karl Fischer moisture determinations were in excellent agreement. Conditioning temperatures of 70°, 77°, and 80° F. were investigated. After 70 days the moisture contents were, respectively, 1.3, 1.1, and 0.82% at these temperatures.

After reaching 1% moisture (77° F., 78 days) samples were stored at 70°, 77°, and 100° F., and after 1, 3, 6, and 12 months, chemical analyses and organoleptic tests were made. Control samples were stored at −30° F. Supplementary storage studies at 117° and 90° F. were also conducted.

Vacuum promoted desiccation when the CaO was packaged in a perforated bill-box *(11)*. In moisture-permeable paper the desiccant performed equally well in 6 oz. cans at pressures from one atmosphere to 0.03 of an atmosphere at temperatures up to 100° F. (Table 5). The difference was attributed to the larger area (300 X) of the paper envelopes.

TABLE 5

Moisture content of orange juice powder as influenced by atmosphere and temperature, 6 oz. cans, IPD

Days	Vacuum		Air	
	70° F.	100° F.	70° F.	100° F.
	%	%	%	%
0	2.83	2.83	2.83	2.83
7	2.35	1.02	2.44	1.10
14	2.17	0.70	2.20	0.86
28	1.91	0.48	1.91	0.57
118	1.17	0.17	1.20	.....
363	0.69	0.12	0.74	0.10

At temperatures above 100° F. the difference in desiccation rate in air and vacuum-packed 6-oz. cans containing powder of 3% moisture became apparent. After 50 hours at 117° F. the air-packed sample had formed a hard cake and had a moisture content of 1.4%. The vacuum-packed powder had formed an easily broken cake and had a moisture value of 1.3%.

That IPD rates are temperature-dependent has been demonstrated *(11, 13, 14, 21)*. This temperature dependence is a reflection of the vapor pressure exerted by the moisture of the powder. Vapor-pressure values are derived from relative humidity data (Figure 1). Rate of moisture loss is a linear function of vapor pressure until vapor pressure is below 2 mm. and the powder moisture is below 1%. The supporting data are in Table 6.

TABLE 6

Influence of powder moisture and temperature on vapor pressure and rate of moisture loss

Moisture in powder	Temp.	Vapor pressure	H_2O loss per week
%	° F.	*mm. Hg.*	*g./100 g. powder*
2.8	100	6.9	1.8
2.8	90	5.1	1.3
2.8	85	4.3	0.9
2.8	80	3.7	0.8
2.8	70	2.7	0.5
1.0	100	2.5	0.3
1.6	90	2.8	0.4
1.9	85	2.9	0.4
2.1	80	2.8	0.4
2.4	70	2.2	0.2

Desiccation rates at various temperatures for 6 oz. cans (202 x 314) and No. 10 cans (603 x 700) are given in Table 7. Conditioning is defined as the time required to lower the moisture content of the powder from 3% to 1%. At 77° F. the powder in No. 10 cans required about 10 days longer to reach the desired moisture level than that packed in 6 oz. cans. Throughout storage the size of container made slight difference in desiccation rate. Desiccation rates at 100° F. of powders in 6-oz. cans were significantly higher than in No. 10 cans at moisture levels above 1%. These data appear in Table 8.

TABLE 7

Moisture content of orange juice powder during conditioning and storage

Days	Conditioning at 77° F.	
	6 oz. can	No. 10 can
	%	%
0	3.0	2.9
30	1.4	1.5
60	1.1	1.2
80	1.0	....
90	....	1.0
100	....	0.9

Days	Storage				
	6 oz. can		No. 10 can		
	70° F.	100° F.	70° F.	77° F.	100° F.
	%	%	%	%	%
0	1.0	1.0	0.9	0.9	0.9
30	0.9	0.3	0.8	0.7	0.4
90	0.8	0.2	0.7	0.6	0.2
180	0.6	0.2	0.6	0.5	0.2
365	0.5				

TABLE 8

Effect of container size on desiccation rate of unconditioned orange juice powder at 100° F.

Days	Moisture, %	
	6 oz. can	No. 10 can
0	2.8	2.8
7	1.0	1.3
14	0.7	1.1
21	0.6	0.9
28	0.5	0.6

At 100° F. unconditioned powder in 6-oz. air-packed cans showed a slight tendency to cake within 7 days. In 6 oz. vacuum-packed cans the powder was free-flowing at the end of this period. In No. 10 cans it became badly caked and shrank away from the can. Powder in a similar No. 10 can packed with 14 10-g. packages of desiccant (symmetrically distributed) caked under the same conditions (7 days at 100° F.) but did not shrink. The final moisture was 1.3%.

The effect of distance of powder from desiccant in No. 10 cans was determined. Longitudinal core samples one-half inch in diameter were removed periodically at distances of 1, 2, 3, and 4 in. from the desiccant. No significant difference in moisture content was noted between the nearest and farthest samples. Another approach was made by placing the desiccant at the end of the No. 10 can. Samples from various depths gave moisture values that were not significantly different. Powder farthest from the desiccant had formed an easily broken cake. The remainder was free flowing.

The 6-oz. cans packed with 10 g. of CaO had a desiccant-area to desiccant-weight ratio of 8.7 square centimeters per gram, while the No. 10 cans with the 140 g. of CaO had an area-to-weight ratio of 2.5. This difference is the probable explanation for the lack of caking in the 6-oz. cans. The fact that slight caking in the No. 10 cans occurred at the bottom may be due to the slight pressure caused by the weight of the powder.

Desiccation rates were measured on sieved and unsieved samples of powder. Two-mm. layers of sieved orange juice powder were exposed to a 2% relative humidity atmosphere at 70° F. The results (Table 9) indicate that the smaller particles desiccate at a more rapid rate than larger, even though the porous structure is the same in both. For example, −60-mesh powder declined from 2.4 to 1.5% moisture in 22 days, while −16+20 mesh powder required 64 days to go from 2.4 to 1.6% moisture.

TABLE 9

Effect of particle size on desiccation rate, 70° F. (2% RH humidity chamber)

Sieved before storage

Days	Mesh		
	−16 + 20	−20 + 40	−60
	Moisture in powder, %		
0	3.3	3.2	2.4
12	2.4	2.2	1.8
22	2.2	2.0	1.5
50	1.8	1.6	1.3
76	1.6	1.4	1.2

The desiccation rates of various-sized particles were measured on the sieved IPD-stored powder after intervals (Table 10). These data indicate that the desiccation rate is increased considerably by diminishing particle size. The drawback likely to be encountered by fine grinding is that the powder will be difficultly soluble as a result of clumping upon initial wetting.

Data obtained after 22 days at 70° F. (Tables 9 and 10) show that desiccation rates in the humidity chamber and the IPD 6-oz. can are the same. Further, the desiccation rate of a particle is unaffected by moisture content of surrounding particles under conditions existing in the IPD 6-oz. can. The reason is that vapor-pressure difference between powder and desiccant is much greater than the difference between particles of different moisture content.

TABLE 11

Ascorbic acid and SO_2 content, feed materials, and powder

	SO_2		Ascorbic acid	
	p.p.m. MFB		mg./100 g. MFB	
	100% OJP[1]	CSS[2] 60–40	100% OJP[1]	CSS[2] 60–40
Feed	182	229	325	191
Powder	149	222	306	191
Conditioned powder	149	181	299	191
After 6 mo. at 70° F.	150	.....	284	188
After 6 mo. at 100° F.	149	149	241	191

[1] Pure orange juice concentrate.

[2] Orange juice concentrate containing 40% corn sirup solids. Data of Mylne and Seamans.

STORAGE STABILITY (OBJECTIVE)

Data in Table 11 indicate that the SO_2 loss (20%) in 100% orange-juice powder occurs only during drying. The 60–40 corn sirup solids product lost 7% of its SO_2 in drying, 13% more by the time conditioning was completed, and another 15% after 6 months at

TABLE 10

Effect of particle size on desiccation rate (6-oz. vacuum-packed cans)

Sieved after storage

	Mesh					
	+16	−16 + 20	−20 + 40	−40 + 60	−60	Not sieved
	Moisture in powder, %					
Original	3.2	3.3	3.2	2.9	2.4	2.9
22 days at 70° F.	2.2	2.2	2.0	1.8	1.3	1.8
7 days at 90° F.	1.6	1.6	1.5	1.3	0.9	1.4
14 days at 77° F.	2.1	2.2	2.0	1.7	1.3	1.8
Undesiccated, 14 days at 77° F.	2.7	2.8	2.8	2.8	2.9	2.8

100° F. Sorber *(19)* has presented evidence that the sulfur in sulfur dioxide that disappears during storage does not reappear as $SO_4^=$ but does appear in the total sulfur determination. The CaO desiccant has been shown to react with CO_2 *(15)* and it is not unlikely that SO_2 reacts similarly.

Ascorbic acid loss in orange-juice powder with no added CSS was about 6% during drying, 2% during conditioning, and 25% after 6 months at 100° F. The sample held at 70° F. one year retained 91% of its ascorbic acid. The ascorbic acid was equally retained by powders in 6-oz. and No. 10 cans. By contrast, the ascorbic acid of the 40% corn sirup solids product, after a 4% decrease during drying, remained undiminished after 6 months at 100° F. Even though loss of ascorbic acid in the 100% orange juice powder is greater than in the 60–40 product at all stages, the quantity remaining in the 100% product exceeds the amount in the 60–40 product by at least 25%.

For 100% orange juice powder the pectinesterase activity was 0.027 unit/ml. in the feed and 0.023 in the powder. The cloud value was 380 on the feed and 370 on the powder after 6 months at 100° F.

The water-soluble color changed so slightly during processing and storage that the change was not visually discernible in the reconstituted juice.

Relative apparent viscosity of reconstituted juice was unchanged (1.06) throughout processing and storage. The consistency of juice from reconstituted powder remained constant.

Storage of undesiccated samples containing 2.0 to 3.5% moisture at temperatures from 77° to 100° F. (conditions likely to be encountered in production and storage) resulted in the data in Table 12. In 2

TABLE 12

Caking time of orange juice powder as influenced by temperature and moisture content

Temp., °F.	Days to caking (undesiccated)					
	2.0	2.3	2.5	2.8	3.3	3.5
	Moisture in powder, %					
77	....	....	....	21	7	7
80	....	....	....	7	5	2
85	21	14	14	4	2	2
90	4	4	2	2	2	2
100	2	2	2	2	2	2

days at 100° F. undesiccated caking samples that had original moisture values of 2.3, 2.8, 3.3 and 3.5% gained moisture (probably by decomposition) to levels of 2.4, 3.0, 3.5, and 3.7%, respectively. These samples had darkened. Samples stored at 90° F. and below did not show darkening so strikingly. This moisture increase in undesiccated samples was also reported by Wong *et al. (24)* and Mylne and Seamans *(11)*.

SUBJECTIVE APPRAISAL

Orange powders were reconstituted by adding 7.34 parts of cold water to one part of powder by weight. This produced a juice of 12% orange solids. Tastings were performed in booths lighted dimly to mask color differences. Twelve judges, experienced in orange juice tasting, compared the samples by triangle taste test. Samples were considered significantly different when the probability level was 0.01 or less *(26)*.

Testing of the feed material and powder (after oil contents were equalized) revealed a preference for the feed. There were 23 correct judgments out of 38 in the triangle test; of those judging correctly 16 preferred the feed.

Powder conditioned at 77° F. for 78 days was not significantly different from unconditioned control powder (18 correct/44 judgments). Storage at 70° F. in addition to conditioning storage was detected in three months (58 correct/108 judgments. Six months at 70° F. after conditioning made the powder very significantly different from unconditioned control powder (32 correct/44 judgments). However, flavor changes at 70° F. were considered mild as evidenced by the fact that the judges were evenly divided in their preferences for the 70° F. 6-month and control powders. After 1 year at 70° F. the preference ratio was 75–25 in favor of the control.

In contrast, storage at 100° F. for 1 month after conditioning caused a flavor difference which was detected by all judges (44 total judgments) as being less palatable than the control powder. At all test periods between 1 and 6 months the powder stored at 100° F. was found less desirable than the −30° F. control. In fact, storage of conditionel powder at 100° F. for 1 month resulted in off-flavors and lack of natural flavor sufficient to cause it to be less palatable than similar material stored at 70° F. for 12 months. After 6 months at 100° F., judges commented that the flavor no longer resembled orange.

Air-packed powders of 1% and 3% moisture stored at 100° F. for 3 months were not different in flavor (17 correct/40 judgments). Likewise, vacuum-packed powders of 1% and 3% moisture were not different after 3 months at 100° F. (14 correct/42 judgments).

Low oil (0.098% MFB) and high oil (0.159%) powders were not found different at any stage of storage. In triangle taste tests the ratio of correct to total judgments was never higher than 17/44.

The taste panel found a difference (38/44 judgments) between SO_2-treated and untreated powder after 14 months at 70° F. The SO_2-treated powder was preferred by 31 of the tasters.

Air- and vacuum-packed powders were not different in flavor up to 6 months at 100° F. (12 correct/40 judgments), although the air-packed material had become caked at a moisture level of 2.8%.

Powder with added oil entrapped in sorbitol was not found to differ appreciably during storage from powders with added oil entrapped in sucrose and dextrose. The ratio of correct to total judgments did not exceed 22/48.

Location of the desiccant in No. 10 (603 x 700) cans at side, center, or end position had little effect on powder flavor during storage. A maximum of 22 correct in 44 total judgments resulted when stored powders with center and side or center and end desiccant positions were compared.

The rate of flavor change during 70° F. storage was similar for powders packaged in 6 oz. and No. 10 cans. After 3 months at 70° F., judges found the conditioned powders different from controls for both 6-oz. cans (58 correct/108 judgments), and No. 10 cans (23 correct/44 judgments).

SUMMARY

Vacuum-dried orange juice powder containing no additive other than $NaHSO_3$ was stored at 70°, 77°, and 100° F. Changes in flavor and chemical composition were evaluated at intervals during storage.

The stability of the entrapped cold-pressed orange oil was excellent whether in sorbitol, sucrose, or dextrose. Powders containing up to 0.11% free oil were equal in storage stability to those containing 0.058%.

The vacuum-packed powder, after 70° F. storage for one year, was equal in flavor to the −30° F. control, when compared by ranking. The triangle taste test showed the 3-month 70° F. sample to be different from the −30° F. control. After 30 days at 100° F. the sample was judged to be different from the −30° F. control.

The IPD desiccation rates of orange juice powder at 70° and 77° F. were about 10% greater in 6-oz. than in No. 10 cans. Location of the desiccant in the No. 10 can had no significant effect on desiccation rate of the powder.

Loss of SO_2 in orange juice without other additive occurred only in the drying process. The consistency of the juice was unaffected and the color but slightly affected by the drying and storage operations.

Under the most adverse conditions used (6 months at 100° F.) 75% of the ascorbic acid was retained.

Acknowledgments

The authors thank E. F. Jansen and C. C. Nimmo for their interest and counsel. The assistance of the following is gratefully acknowledged: E. C. Marshall, E. F. Potter, and J. S. Wilbur.

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A Strain Gage Pea Tenderometer. I.

Instrument Description and Evaluation[a,b]

(Manuscript received May 15, 1957)

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OBJECTIVE MEASUREMENT of the quality of peas using a semiautomatic testing device is a much desired goal in the green pea industry. A Strain Gage Pea Tenderometer, developed and evaluated by the Department of Food Technology, M.I.T., shows considerable promise. A description of the apparatus and methods used to evaluate its effectiveness are reported in this paper.

The great differences in quality that exist between peas in different stages of maturity necessitate methods for evaluating quality. Four basic evaluation techniques — organoleptic, chemical, physical, and mechanical—are currently in use. Each has certain disadvantages. The organoleptic technique is subjective and often unwieldy; chemical methods, although accurate, are slow; and physical or mechanical methods, although rapid, are difficult to standardize.

A large number of mechanical devices for measuring pea maturity have been developed in the past quarter of a century. These include the puncturemeter, the texturemeter, the maturometer, and the American Can Company Tenderometer, which has the widest use today *(1, 3, 5, 7)*. Most of the methods now in use have a distinct disadvantage in that they give only an average value of the quality of the sample *(6)*. However, the subjective and brine flotation tests give some indication of the distribution of quality in a sample.

Pea testing on the strain gage denture tenderometer has given results which show a high degree of correlation with the subjective results obtained with taste panels and the results obtained with the Canco Tenderometer. Since one pea at a time is presented to the denture tenderometer, the results may either be used to obtain an average for all the peas in a sample or presented for each pea to show the distribution of individual pea quality. However, the denture tenderometer requires the use of skilled personnel and, since its operation is manual, it cannot perform measurements with great speed *(11)*.

Accordingly, an instrument was designed that not only utilizes the basic masticatory motion and dental surfaces of the denture tenderometer but also operates semi-automatically, receiving and chewing peas one at a time, recording the physical properties in digital form, and cleaning itself after each single bite or measurement.

DESCRIPTION OF APPARATUS

Relative positions of the mechanical and electronic components of the instrument are depicted symbolically in a block diagram in Figure 1.

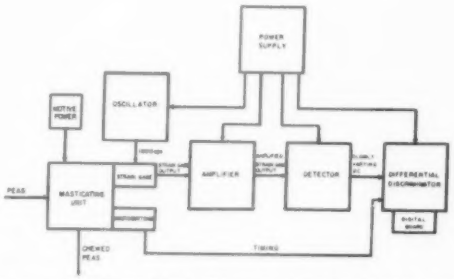

Figure 1. Symbolic block diagram showing relative mechanical and electronic positions of components of Strain Gage Pea Tenderometer.

A representative sample of peas is placed in the feed mechanism which feeds peas one at a time to a two-molar masticating unit. The resistance to chewing caused by the pea is reflected as a change in strain on the main drive shaft of the masticator which, in turn, is sensed as a change in resistance by a bonded wire resistance strain gage fixed to the shaft. The change in strain gage resistance is amplified sufficiently to energize a counter mounted on a digital board containing ten such counters. The relative physical resistance to chewing determines which counter will register a count. The less resistance offered or the less mature the pea, the lower will be the counter energized, and vice versa.

A photograph of the feeding and masticatory assembly is shown in Figure 2.

The masticatory assembly is designed to receive peas individually at the rate of 20 per minute, to chew them one at a time between two pairs of opposing molars, and to clean itself after each bite so that it is ready for the next pea. The entire apparatus is actuated by a geared-down electric motor connected to it by conventional mechanical shafts, gears, and chain drives.

The feed mechanism allows one pea at a time to fall into a cuplike receptacle, which is split and held

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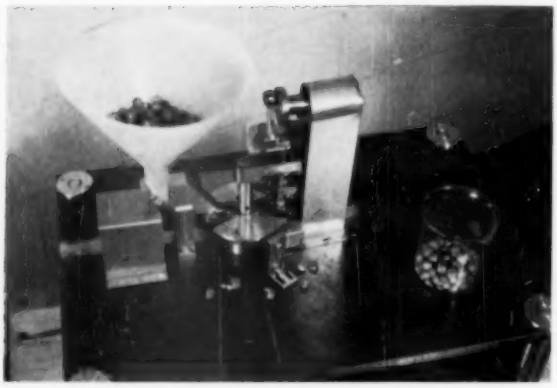

Figure 2. Masticatory section of Strain Gage Pea Tenderometer.

together by springs. This receptacle is part of a circular rotary table. The entire table rotates through 180° until the pea-containing receptacle is directly between two fully opened pairs of opposing upper and lower molars. The teeth are commercial mechanical, or flat surface, denture molars made of Vitallium (registered trademark of Austenal Laboratories, Inc.), a cobalt chromium alloy.

When the rotary motion ceases, a vertical drive shaft, to the lower end of which is attached the upper pair of molars, descends downward, preceded by a steel spade which acts as a wedge to spread apart the two halves of the split receptacle. The pea then rests freely on the lower pair of molars and is chewed by a simultaneous combination of (1) the upper molar's downward crushing motion, and (2) a 2-mm. lateral shearing motion of the lower molars.

The reaction force of the pea to mastication is sensed by a strain gage fixed to the drive shaft. A dummy temperature compensating strain gage is bonded to the drive shaft bearing. The strain gages are Baldwin-Lima-Hamilton Corp. SR-4, type A-18 (nominal resistance 120 ohms, gage factor 1.8, and size $\frac{1}{16}$-inch long and $\frac{1}{8}$-inch wide).

As the pea is chewed, another pea is dropped into a second, similar, split cup at the feed position, which is diametrically opposite the first or filled cup on the rotary table. When mastication is completed, the upper pair of molars and its associated spade withdraw. The first receptacle then closes upon the pea debris and begins a 180° rotation to the teeth. Stiff bristled brushes on the under side of the rotary table scrub the remaining debris from the lower molars, and the moving brushes are, in turn, cleaned by similar brushes rigidly fixed to the base of the apparatus.

After the rotary table has passed through about one quarter of a revolution, the split cup is again opened by means of a protruding screw on one-half of the cup, which engages a rigid rubber pin during its travel. The cup is thus opened sufficiently to allow the pea debris to drop out of the cup.

The entire feeding, chewing, and self-cleaning operation takes place at a rate of about 20 peas per minute.

Both the regulated and unregulated electrical power required for the electronic components are furnished by a conventional two-channel regulated power supply modified from standard circuit diagrams to give the specifications required and which operate directly from a 110-volt line *(2)*. Figure 3 is a diagram of this circuit, which employs a high gain feedback loop to compare the output voltage with a standard voltage derived from a glow discharge tube. Both output channels operate at a regulated 300 volts. The channel powering the oscillator-amplifier-detector elements has a capacity of 150 ma and that powering the differential discriminator, a capacity of 75 ma.

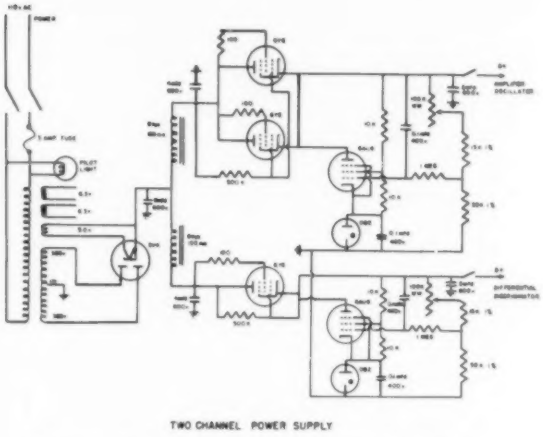

Figure 3. Circuit diagram of two channel power supply.

The strain gages form one side of a Wheatstone bridge. The bridge voltage is supplied by a standard strain gage oscillator designed for 1000 cps but operating at 1300 cps *(4)*. Figure 4 is a circuit diagram of this component, available commercially with provision for strain gage input.

As in most oscillation circuits, the oscillation is created by a positive feedback loop, with a Wien bridge used to determine the frequency of oscillation. The wave is fed to a phase inverter which, in turn, feeds two output power tubes in push-pull. Amplitude is controlled by a potentiometer in the grid of the inverter stage. The oscillator is operated for stability, with 5 volts rms output to the strain gages.

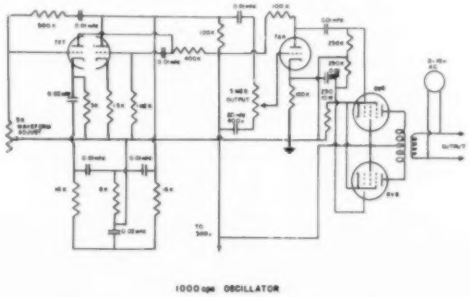

Figure 4. Circuit diagram of oscillator.

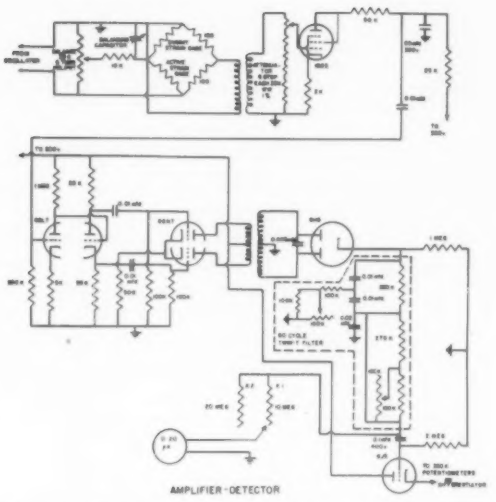

Figure 5. Circuit diagram of amplifier-detector section of Strain Gage Pea Tenderometer.

The Wheatstone Bridge output feeds through a step-up transformer and a six-stage precision attenuator to a low noise tube, which is the first stage of a conventional strain gage amplifier *(4)*. Figure 5 is a diagram of the amplifier-detector circuit. The signal is further amplified in subsequent stages including a push-pull output stage and is then fed to a full-wave rectifier and an impedance matching transformer.

Conventional detector and filter circuits were applied to the unit at this point in order to feed a DC signal to the differential discriminator. The latter circuit was especially designed to obtain a digital output. Although the oscillator-bridge-amplifier circuits are conventional, the remaining circuitry was not available and had to be created for the purpose.

A full-wave rectifier with a high-load resistance acts as a detector to convert the amplified high frequency AC to a DC signal. A twin-T 60-cycle filter is inserted between the detector and the output cathode follower to reject 60-cycle noise to ground. The cathode follower is used as an impedance matching element between the amplifier-detector and the differential discriminator.

Figure 6 is a circuit diagram of the differential discriminator, which analyzes the pulse heights received from the active strain gage and actuates the proper counter. The cathode-follower output feeds ten potentiometers on the differential discriminator chassis, which determine at what signal value each counter will be actuated.

Each triode unit is used to operate a single plate relay. If a plate relay throws, a single 110-volt relay trips and is locked in an activated position until the 110-volt power is interrupted. The contacts of the 110-volt relays are arranged so that only one counter operates at a time. The 10 potentiometers are set so that the first triode responds to the smallest signal, or that obtained from the tenderest peas, and the tenth triode to the largest signal, or that received from the toughest peas.

A 110-volt relay in the differential discriminator chasses controls the power to the counters and to the plates of the discriminator triodes. The entire unit is timed with the aid of two microswitches on the input transducer to operate in the following cycle. As the pea is masticated, the plate relays activated by the signal momentarily close. This locks the associated 110-volt relays. As the tooth is lifted from the pea, the 110-volt relay in the differential discriminator chassis is mementarily activated. This interrupts the plate voltages on the triodes so that the energizing of another plate relay by any secondary pulses is prevented and the counters are activated. Just before the next pea is masticated, the 110-volt relays are momentarily released by the 110-volt relay on the differential discriminator chassis in order to prevent spurious counting. The pea is then chewed and the cycle is repeated. The timing is planned with a view to reject spurious signals and to ensure complete deactivation of plate and 110-volt relays.

EXPERIMENTAL PROCEDURE

Initial calibration tests were carried out to determine settings of the gates to the counters or the electronic equivalents of the levels of maturity of individual peas that cause each counter to register a digit. These calibration studies served to evaluate the instrument on a preliminary basis, rather than to measure any characteristics of the sample of peas.

Peas for the tests were supplied by a Maine canner. The peas were field-run and were vined in a mechanical viner on the same morning as picked, but not further processed. They were then placed in polyethylene bags that each held about 2 pounds of peas. The bags, when filled, were sealed with cellophane tape, placed in a cardboard box, iced, and flown to Boston by Air Express. The peas arrived at the laboratory within 4 hours after being picked.

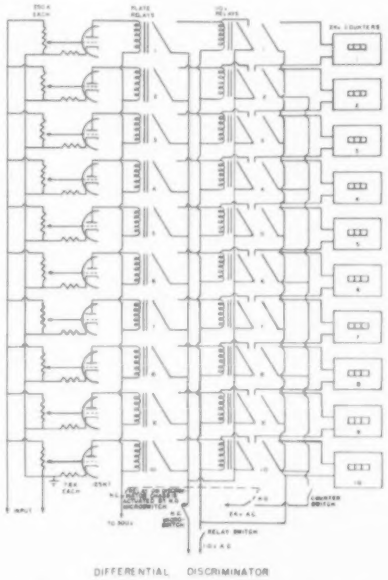

Figure 6. Circuit diagram of differential discriminator showing counters, mounted to give digital output.

The basic experimental procedure was to test 100 peas in the pea tenderometer. As an index of quality distribution, use was made both of the results indicated on the counters and visually observed pulse heights measured on a cathode ray oscilloscope in parallel with the input to the digital board. One hundred peas from the same batch were tested simultaneously in the strain gage denture tenderometer as a reference standard. In this instance the maximum vertical deflection in the force-time figures occurring on the first bite was used as the quality index *(11)*.

In separate tests with both instruments, 100-unit samples of both random sized peas and selected uniform sized peas were studied. The selective sizing of the peas was performed by use of a template with holes of 10 different diameters, with the maximum size being 10 mm. to accommodate the cups which transfer the peas to the teeth. Although 100-unit samples may be insufficient to give accurate results *(9)*, this number of units per sample was relatively convenient to handle and gave reproducible results.

The distribution results from the pea tenderometer were compared with those from the denture tenderometer, and both results were averaged and compared with Canco tenderometer ratings and with data on contents of alcohol insoluble solids and canned product grade scores for samples from the same batch furnished by the canner's quality control staff.

A preliminary series of tests with the pea tenderometer served as a means of setting the gates. The differential input to the discriminator required to include all the peas in ten evenly spaced maturity categories was found to be 3 volts between gates. The first counter was set at 3 volts at the lower limit to ensure that the inherent noise of the instrument would not trip the first counter. At the upper limit the first counter was set at 6 volts. The tenth counter had a lower gate setting of 30 volts and no upper limit, so that this counter would indicate all peas that should properly fall into this category as well as any unusual peas that might properly have a higher quality index.

Individual pens of both the selected and the random-sized lots were fed to the strain gage pea tenderometer, and the distributions of maturity indices were recorded from both the counters and the cathode ray oscilloscope pulse heights. Use of the oscilloscope was necessitated by the need for a check of the operation of the relays within the digital board. The vertical pulse deflection of the cathode ray instrument is an accurate index of the amplified electrical equivalent of pea maturity as sensed by the active strain gage.

The technique used with the denture tenderometer to obtain a standard distribution of maturity indices was to record the first-bite vertical deflections of the force-time figures for the 100 peas in the sample. The 100-unit averages of these deflections for the selected sizes were used for comparison with the Canco tenderometer data sent by the packer.

To obtain as a reference basis the maturity distribution of individual peas, the minimum individual deflection in a 100-unit sample tested in the denture tenderometer was subtracted from the maximum deflection to get the total range of deflections. This result was divided by 10, the number of categories it was desired to establish, which was equivalent to the number of counters on the strain gage pea tenderometer. The quotient was the minimum range of individual deflections indicated by the denture tenderometer for each of ten maturity categories.

To ensure that peas of all possible degrees of maturity in different series of 100-unit samples could be included in this type of analysis of maturity distribution, the assumption was made that the total range of individual deflections that might be recorded would be somewhat greater than the standard range as calculated above for the denture tenderometer test. For this purpose it was assumed that the minimum deflection would be somewhat smaller than the smallest deflection noted in the reference test with the denture tenderometer. The ranges of deflection in 10 maturity categories were then calculated by (a) adding one-tenth of the assumed total range to the smallest deflection recorded by the denture tenderometer to obtain the upper limit of the first maturity category, (b) adding the same value to the first category's upper limit to obtain the upper limit of the second category, and (c) so on through the tenth category. The individual deflections for each 100-unit sample were then examined, and the number of peas having deflections falling between the lower and upper limits of each maturity category thus calculated was counted and recorded, to secure the distribution of maturity indices in the several categories.

RESULTS AND DISCUSSION

The distribution of samples of 10 mm. diameter peas according to the ten-category maturity indices is shown in Figures 7 and 8 for two series of experiments. In both series the distributions of ungraded or random sized peas in the several categories as indicated by the pea and denture tenderometers show considerable differences, evidenced by the sharp peaking in Figure 7 as opposed to the flatness of Figure 8. This result was not unexpected since the dependence of the maturity index on unit size has been previously demonstrated *(7, 8, 9)*.

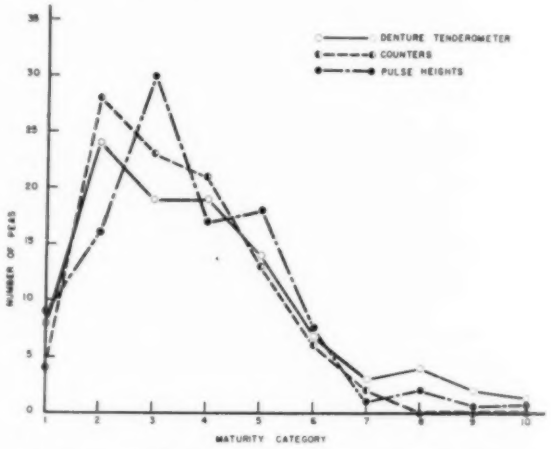

Figure 7. Distribution of maturities of raw field run early season peas, as determined by the Strain Gage Denture Tenderometer and the Strain Gage Pea Tenderometer (unit counters and oscillograph pulse heights).

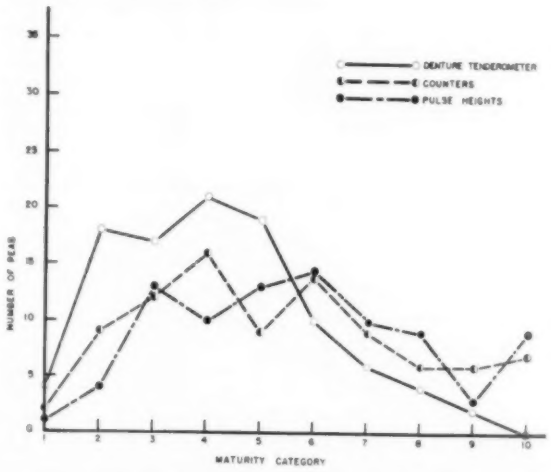

Figure 8. Distribution of maturities of raw field run late season peas, as determined by the Strain Gage Denture Tenderometer and the Strain Gage Pea Tenderometer (unit counters and oscillograph pulse heights).

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Measurements of sizes of field-run peas by a template divided into 10 size classifications to determine the distribution of pea sizes gave distribution curves that were approximately mirror images of the maturity index distribution curves for selected sizes of peas. This indicates that, contrary to reports in the literature, maturity index cannot be measured by unit size. However, since ungraded peas vary in size, and since the output of instruments having simulated masticatory motion is dependent on size *(10)*, the factor of size must be eliminated to achieve statistically significant results. Accordingly the results obtained for selected peas of uniform size were considered significant in these studies.

The distributions of maturities of selected sizes of peas as measured by the pea and denture tenderometers were in close agreement. There was also close agreement between cathode ray oscilloscope pulse height and counter distributions, especially in the last series, indicating that the operation of the relay-actuated counters was satisfactory.

The approximate equivalent Canco tenderometer ratings for the 10 maturity categories based on data previously reported *(11)*, were as follows:

Category	Equivalent Canco rating
1	0– 75°
2	75– 90°
3	90–105°
4	105–120°
5	120–135°
6	135–150°
7	150–165°
8	165–180°
9	180–195°
10	195–and above

These equivalents and the number of peas falling into each category reveal the extremes of maturities of individual peas in a lot and thus show clearly the ability of the Canco tenderometer to submerge abnormal distributions in a single average value.

Probably the most significant feature of the distribution data is the sharpness of the peaks obtained in the earlier test series, which is indicative of a relatively uniform product. In the final test series the peak is more level, indicative of a lessening of product uniformity as the season progresses. This is in agreement with observations made by the quality control staff of the pea canner, which showed a significant quantitative increase in the number of mature peas rejected in the plant's brine flotation equipment later in the season.

CONCLUSIONS

An electronic instrument has been designed for obtaining information semi-automatically and rapidly on the distribution of maturity of peas in a lot. The output of this instrument is in a convenient digital form, which enables the operator to observe the results directly at any time during testing.

Although it was the intention of the authors only to build a new instrument, distribution results from the unit when compared with similar results from the previously validated strain gage denture tenderometer were found to be in close agreement. Average results from the denture tenderometer correlated well with industrial standards for the lots tested.

Two findings with the new device which will probably require confirmation were (1) the disclosure of extremes of maturity of individual peas in a lot having a low average rating as determined by the Canco tenderometer, and (2) the agreement of distribution results with the packer's qualitative observations of a lowering of pea uniformity as the season progresses.

On the basis of these preliminary and very encouraging results, it was considered that the Strain Gage Pea Tenderometer has sufficient potential to warrant refinements and further investigation as a research tool.

Acknowledgment

The authors wish to express their appreciation to Mr. William Strovink of the Biology and Food Technology Machine Shop at the Massachusetts Institute of Technology. His efforts contributed greatly to the design and construction of the mechanical apparatus.

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The Effect of Several Antifungal Antibiotics on the Growth of Common Food Spoilage Fungi

(Manuscript received July 12, 1958)

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THE FUNGAL SPOILAGE of food is familiar to every handler of perishable foods and food products. Fresh fruits and vegetables are plagued with an array of mildews, blights, rots, spottings, and wilts of fungal origin. In meat and fish, while bacterial spoilage is of dominant importance, the slower growing yeasts and molds become more important when bacterial growth is hindered. Dehydrated, smoked, and salted fish and meats frequently have a moisture content quite adequate for the development of molds and yet tend to hinder bacterial growth. Despite the potential control of fungal food spoilage by the use of antifungal antibiotics, only a limited amount of work has been done on this approach.

Several antifungal antibiotics have been available for some time but have received limited attention. Griseofulvin has been the subject of several investigations *(4, 5, 6, 7)*. Stubbs *(23)* reported the control of *Botrytis cinera* infections of lettuce and *Alternaria solani* infections of tomatoes by foliage spray with griseofulvin. Griseofulvin has also been shown to be inhibitive to the growth of fungi responsible for onion rot, gray mold of lettuce, and chocolate spot of beans *(20)*, and promising in the control of *Fusarium* and a variety of root rots *(9)*. Since its isolation in 1947 by Leach, Ford, and Whiffen *(18)*, acidione has proved to have a fairly broad spectrum of antifungal activity. Actidione has been demonstrated to inhibit the growth of most yeasts and phytopathogenic fungi *(17, 28)*. It has been shown to protect beans from powdery mildew *(25, 26)*, decrease in incidence of cucumber scab *(12)*, control cherry leaf spot *(10, 14, 16)*, and control wheat rust caused by *Puccinia graminis* var. *tritici (27)*. Fungizone, a preparation containing the two antifungal antibiotics amphotericin A and amphotericin B, has received little nonmedical study. Gold *et al. (15)* tested a number of fungi for sensitivity to the amphotericins and showed that a mixture of the two antibiotics was highly active against most of the fungi tested. Very little published information is available on the use of either nystatin or rimocidin in the field of plant pathology or food technology. Neither of these antibiotics was effective in protecting beans from powdery mildew *(30)* nor in the prevention of fish spoilage *(19)*. However, Tarr *et al. (24)* found rimocidin useful in preventing yeast growth on fish treated with chlortetracycline and Ayres *et al. (1)* reported that rimocidin was effective in inhibiting the development of yeast indigenous to dressed poultry. Nystatin was demonstrated to be active, *in vitro*, against a wide variety of fungi by Brown and Hazen *(8)*. There was no published information available concerning the properties or activity of myprozine.

The purpose of this investigation was to determine the activity spectrum of available antifungal antibiotics against a variety of yeasts and molds responsible for the spoilage of foods. Two testing procedures, an agar plate method and a shake culture technique, were compared and used to determine the antifungal activity of six antibiotics and sorbic acid against sixteen yeasts and molds of economic importance.

EXPERIMENTAL

Antifungal agents. The 6 antifungal antibiotics and sorbic acid used in this study were obtained from the following sources: sorbic acid (Batch 236, S1123) from the Carbide and Carbon Chemicals Corporation; griseofulvin (57RT, S44) from Merck and Company; acidione from The Upjohn Company; fungizone (Batch P-1) and nystatin (Mycostatin, 133087-023) from the Squibb Institute for Medical Research; rimocidin (934 γ/mg.) from Charles Pfizer and Company; and myprozine (Antifungal A-5283, R146) from the Lederle Laboratories of the American Cyanamid Company.

Test organisms. Sixteen different common food spoilage fungi were used as the test organisms. These included both yeasts and molds. Pure cultures of these organisms were obtained from the culture collection of the Department of Food Technology, University of Illinois, the Northern Regional Utilization Research Branch, or isolated from a spoiled food.

Preparation of inoculum suspensions. To prepare a heavy uniform suspension of the test fungus, a potato dextrose agar slant was inoculated with the organisms from the stock culture and incubated for 96 hours at 25° ± 2° C. The growth from the slant was transferred to a 250-ml. Erlenmeyer flask that contained 50 ml. of sterile Sabouraud dextrose broth adjusted to pH 4.0 with HCl. After 72 hours' incubation at 25° ± 2° C. on a reciprocating shaker the supernatant broth was decanted and the sediment taken up with 100 ml. distilled water. If the test organism was a mold, the pellets of mycelial growth were disintegrated and homogenized in a sterile Waring blender jar. When the test fungus was a yeast, a uniform suspension was obtained by vigorous shaking. The suspension was then adjusted to an optical density of 0.60 with sterile distilled water and stored in a screw cap bottle at 0° C. until used.

Inhibition studies. The antifungal activity of each test compound was evaluated by both an agar plate method and a shake culture technique. Sabouraud dextrose agar with a pH of 5.6 was used as the plating medium for all of the organisms. The shake culture broth was composed of 1.0% peptone and 4.0% dextrose, and was acidified to pH 4.0 with HCl.

Both the solid and liquid media were prepared in one-liter amounts and autoclaved. When the media had cooled, 0.10 g. of a test antibiotic or 1.0 g. of dry sorbic acid was added to the one liter of medium. Antifungal agents were incorported into the broth or agar by mixing in a sterile Waring blender jar. Antibiotic-free broth or agar were used to dilute the original 100 p.p.m. and 1,000 p.p.m. suspensions to the desired concentrations.

In the agar plate method, 25 ml. of the agar containing the substance to be tested were placed into a Petri dish with a sterile volumetric pipette. After solidification of the agar

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one drop of the suspension of the test organisms was placed in the center of the plate with a loop of 4.0 mm. inside diameter. The plate was incubated in an upright position for not more than 48 hours, and then inverted to prevent the seeding of new colonies. An incubation temperature of 25° ± 2° C. was used throughout the inhibition studies. After 96 hours of incubation the diameter of the colony was measured and the per cent inhibition of growth was calculated using the following formula:

$$\% \text{ Inhibition} = 100 - \frac{\text{Radial growth of test plate in mm.} \times 100}{\text{Radial growth of control plate in mm.}}$$

In order to determine whether or not the concentration of the test compound which gave complete inhibition for 96 hours would permit subsequent growth, a plate which was negative after 96 hours of incubation was incubated for an additional 10 days. After a total incubation time of 2 weeks the presence or absence of growth was noted and the concentration of the test compound which completely inhibited the growth was recorded as the fungistatic concentration of the given compound against the specific organism.

To determine the inhibitory concentration of the test compound by the shake culture technique, 25 ml. of the liquid medium were placed in a cotton-plugged 250-ml. Erlenmeyer flask. The flask was then inoculated with one drop of the test organism suspension and placed on a shaker. After 96 hours of incubation the amount of growth was estimated. The relative turbidity of the broth was the criterion by which the amount of yeast growth was estimated, while the number and size of mycelial pellets was estimated to evaluate the growth of mold.

A flask which was negative after 96 hours of incubation was subcultured by transferring a loopful of the broth from the negative flask into a 50-ml. Erlenmeyer flask which contained 10 ml. of test compound-free medium. The flask was placed on a reciprocating shaker and incubated for 72 hours. At the end of this incubation period, the presence or absence of growth was recorded.

All tests were run in duplicate and appropriate controls were included.

RESULTS AND DISCUSSION

Per cent inhibitions of the test fungi by various concentrations of the antifungal antibiotics and sorbic acid as determined by the agar plate method are given in Table 1. The test compounds were arranged in the table in order of their over-all effectiveness. In the testing procedures used in this investigation the yeasts and molds were grown under near optimum conditions with a controlled temperature and adequate nutrients. Hence, the concentration of antibiotic necessary to suppress growth in this study would be expected to be greater than that necessary under conditions less favorable for fungal growth. Therefore, it was not surprising that Napier and Turner *(20)* demonstrated complete inhibition of *Botrytis cinera* by 20 p.p.m. of griseofulvin under laboratory conditions not very favorable for the growth of the mold, while the results obtained in this investigation showed only 60.7% inhibition by 100 p.p.m. of griseofulvin. And Zaumeyer *(29)* reported the preharvest control

TABLE 1

Effect of antifungal antibiotics and sorbic acid on the growth of various fungi in agar plate culture

Test compound	Conc. p.p.m.	Per cent inhibition of growth after 96 hours incubation at 25 ± 2° C.															
		Absidia sp.	*Alternaria sp.*	*Aspergillus niger*	*Botrytis cinera*	*Fusarium sp.*	*Mucor mucedo*	*Oidium lactis*	*Penicillium digitatum*	*Penicillium expansum*	*Penicillium sp.*	*Rhizopus sp.*	*Rhodotorula gracilis*	*Saccharomyces cerevisiae*	*Schizosaccharomyces fructicola*	*Torulaspora rosei*	*Zygosaccharomyces barkeri*
Sorbic Acid	500	100	100	57	100	100	100	100	100	100	100	100	100	100	100	100	37
	100	0	41	0	39	47	28	0	21	26	33	0	0	20	0	10	21
	50	0	19	0	0	34	16	0	0	0	33	0	0	10	0	0	11
Griseofulvin	100	36	60	47	61	47	11	0	46	23	65	0	0	0	100	0	0
	50	33	52	45	59	45	5	0	46	19	50	0	0	0	84	0	0
	25	29	48	35	57	32	2	0	46	1	10	0	0	0	84	0	0
Actidione	100	62	19	72	.....	100	86	0	.....	93	100	87	100	.....	.....	.....	.....
	50	52	16	59	.....	83	71	0	.....	85	100	63	63	.....	.....	.....	.....
	25	35	15	39	.....	70	56	0	.....	63	84	35	32	.....	.....	.....	.....
	10	.....	.....	.....	100	.....	.....	.....	100	.....	.....	.....	.....	100	100	100	100
	5	.....	.....	.....	100	.....	.....	.....	100	.....	.....	.....	.....	100	100	100	100
	1	.....	.....	.....	100	.....	.....	.....	81	.....	.....	.....	.....	0	75	91	33
Fungizone	100	63	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100
	50	59	100	100	100	63	100	80	100	100	100	61	100	100	100	100	33
	25	47	98	72	100	38	100	63	100	100	100	28	100	100	100	0	0
	10	28	78	65	91	12	100	26	74	94	100	8	100	82	100	0	0
	5	0	68	36	68	0	100	0	52	75	100	0	50	9	97	0	0
	1	0	49	9	0	0	0	0	3	27	50	0	0	9	0	0	0
Nystatin	100	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
	50	.....	.....	.....	.....	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	.....
	25	.....	100	.....	.....	.....	.....	100	100	.....	.....	.....	100	.....	.....	.....	100
	10	48	99	100	100	33	100	80	97	100	100	0	80	100	100	90	28
	5	19	74	28	100	15	100	38	91	62	100	0	38	100	100	20	22
	1	0	54	0	100	0	14	0	83	0	0	0	0	0	0	0	0
Rimocidin	25	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	10	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	5	37	79	100	68	100	98	100	100	100	100	100	100	100	100	100	100
	1	23	18	91	0	40	0	25	5	9	100	0	0	0	59	0	98
Myprozine	10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	5	100	100	100	100	76	100	99	100	100	100	100	100	100	100	50	100
	1	18	39	28	100	26	10	3	32	0	98	0	0	0	100	10	0

of several fungal diseases with 2 p.p.m. actidione while only one mold was controlled by this low level of the antibiotic under the conditions of testing in this study. Most of the molds were partially inhibited by griseofulvin, but the per cent inhibition did not change markedly with dilution suggesting a very low dilution coefficient for this compound. Various investigators have shown that concentrations of from 0.01% to 0.10% (100–1,000 p.p.m.) sorbic acid effectively controlled the growth of fungi in a variety of food products *(2, 3, 13, 21, 22)*, which concurred with the complete inhibition of most yeasts and molds by 500 p.p.m. of sorbic acid as reported in Table 1.

Absidia sp. appeared to be the least sensitive of the test fungi to the inhibitory action of the antibiotics, while *Sclerotinia fructicola* and *Botrytis cinera* appeared to be the least resistant. Hence, the employment of the latter two molds as test organisms in the screening of good antifungal antibiotics would appear undesirable unless the screening was directed towards the control of a problem in which these molds were specifically involved.

A comparison of the concentrations of antibiotics necessary to produce complete inhibition of the test fungi for 96 hours by both the agar plate and shake culture methods is given in Table 2. These results show that the concentrations necessary for the complete inhibition of the test fungi were essentially the same for both methods. Both methods were easily reproducible and efficient in the evaluation of the antifungal activity of the test compounds. However, measurements of the sizes of the colonies in the agar plate procedure provided a more sensitive estimation of the inhibitory activity of increasing amounts of the test compounds. In the shake culture technique, evaluation of the amount of growth in the positive cultures was limited to the descriptive terms of heavy growth, moderate growth, slight growth, and no growth, while in the agar plate method a reproducible percentage inhibition could be calculated. For this reason the complete data, as was given in Table 1 for the agar plate method, was not included in table form for the shake culture technique. Such data would have been merely a repetition of Table 1 with only minor exceptions. On the other hand, the shake culture technique provided a more rapid method for the determination of the inhibitory concentration of the antifungal agents. However, since a number of dilutions of each test compound had to be made, this procedure required a considerable amount of shaking equipment.

All of the antifungal agents were at best only slightly soluble in water and fungizone and griseofulvin could be considered insoluble. Since these agents had no common solvent, the compounds were added directly to the media. This procedure avoided any variation which would have resulted from the effect of the various solvents on the growth of the organisms or the variations in the rates of diffusion of the solvents through the agar. Agitation of the liquid medium provided optimum growth conditions for the fungi by insuring adequate aeration, and also kept the aqueous insoluble compounds suspended throughout the medium. Thus, the test organisms were in constant contact with the antifungal agents which were either dissolved or suspended in the liquid medium.

In 65% of the tests which showed complete inhibition for 96 hours by either the agar plate or shake culture method no further growth was noted by extending the incubation of the agar plates to 2 weeks or by subculturing the shake cultures and incubating an additional 72 hours. In the remaining 35% an increase of from 2X to 5X the concentration of the antibiotic was necessary for complete inhibition by these supplimental tests.

The advantages to be gained by the use of antibiotics in the prevention of food deterioration, both preharvest and postharvest, have been described by Zaumeyer *(29)* and Deatherage *(11)*, respectively. Results of this investigation have clearly shown that a wide range of fungi responsible for the deterioration of food can be controlled in the laboratory by low concentrations of several antifungal antibiotics. The

TABLE 2

Concentrations of antifungal agents necessary for complete inhibition of growth of various fungi for 96 hours in agar plates and shake cultures[1]

Fungus	Concentration in p.p.m.											
	Sorbic Acid		Actidione		Fungizone		Nystatin		Rimocidin		Myprozine	
	Agar	Broth	Agar	Broth	Agar	Broth	Agar	Broth	Agar	Broth	Agar	Broth
Absidia sp.	500	500	>100	100	>100	>100	100	100	25	25	5	25
Alternaria sp.	500	500	>100	100	50	50	25	50	10	10	5	10
Aspergillus niger	1000	500	>100	100	50	100	10	25	5	10	5	5
Botrytis cinera	500	100	1	5	25	5	1	5	5	5	1	1
Fusarium sp.	500	100	100	50	>100	100	50	50	10	5	10	10
Mucor mucedo	500	100	>100	100	5	1	5	5	5	5	5	5
Oidium lactis	500	500	>100	100	100	50	25	25	10	10	10	10
Penicillium digitatum	500	100	5	5	25	10	25	25	5	10	5	5
Penicillium expansum	500	500	>100	100	25	25	10	25	5	5	5	10
Penicillium sp.	500	500	50	25	5	5	5	5	1	5	5	1
Rhizopus sp.	500	500	>100	50	100	>100	100	50	5	5	5	5
Rhodotorula gracilis	500	500	100	100	10	10	25	10	5	5	5	5
Saccharomyces cerevisiae	500	500	5	5	25	5	5	10	5	5	5	5
Scerotinia fructicola	500	100	5	5	10	1	5	5	5	5	1	5
Torulaspora rosei	500	500	5	10	50	25	50	25	5	5	10	5
Zygosaccharomyces barkerii	1000	500	5	10	100	50	25	25	5	10	5	5

[1] All test organisms grew in both agar and broth containing 100 p.p.m. of griseofulvin except *Sclerotinia fructicola* which was completely inhibited in agar at this concentration.

ultimate practical use of these antibiotics in the control of food spoilage will depend upon further information concerning their toxicity, stability, degradation products, if they undergo degradation, methods of application, and economic considerations.

SUMMARY AND CONCLUSIONS

The effectiveness of six antifungal antibiotics and sorbic acid in inhibiting the growth of 16 common food spoilage fungi was evaluated. Two testing procedures were used, an agar plate method and a shake culture method. Results obtained with the two procedures were comparable. Advantages and disadvantages of the two test procedures were discussed.

Antifungal antibiotics arranged in order of decreasing effectiveness in producing complete inhibition of the test fungi are myprozine, rimocidin, nystatin, fungizone, actidione, and griseofulvin. Myprozine was only slightly more effective than rimocidin. All test organisms were completely inhibited for 96 hours by 25 p.p.m. or less of these two antibiotics, or by 100 p.p.m. of nystatin, the next most effective antibiotic. Fungizone at a concentration of 100 p.p.m. inhibited all but 3 of the test fungi for a 96-hour period. The concentration of actidione necessary for complete inhibition for 96 hours varied from 1 p.p.m. to greater than 100 p.p.m. Three of the four test yeasts were completely inhibited by 5 p.p.m. of actidione. Griseofulvin, the least active of the test antibiotics, was not active against the yeasts and only one mold, *Sclerotinia fructicola*, was completely inhibited for 96 hours by 100 p.p.m. of this antibiotic.

Of the fungi tested, *Absidia sp.* was the most resistant to the inhibitory action of the test antibiotics, while *Sclerotinia fructicola* and *Botrytis cinera* appeared to be the least resistant.

All test fungi except *Aspergillus niger* and *Zygosaccharomyces barkerii* were completely inhibited for 96 hours by 500 p.p.m. of sorbic acid. These two fungi were not inhibited by 1,000 p.p.m. of sorbic acid when the agar plates were incubated for two weeks or 96-hour shake cultures were subcultured.

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Application of Flavor Enzymes to Processed Foods. I.

Panel Studies[a]

(Manuscript received May 31, 1958)

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SCIENTISTS RECOGNIZE that the characteristic flavors of fruits, vegetables, and other fresh foods are caused by chemical compounds produced by the organisms as a result of their normal metabolic processes. This is also true for many other properties of fresh biological materials. To preserve these foods and materials, the metabolic processes have to be arrested. This can be done by substantially destroying or inactivating the enzymes, and for many years, foods have been stabilized in this way. However, certain changes in flavor usually occur during heat stabilization. These changes may consist in loss of flavor or in the development of off-flavors.

In previous publications *(1, 2)*, it has been reported that non-volatile, relatively heat-stable compounds, present in foods, will survive heat processing and that the flavor precursors or progenitors appear to be among them. It follows then that these flavor precursors can be converted to flavor by the addition of specific, appropriate flavor enzymes, thus regenerating fresh flavor in processed foods. In other cases, the fresh flavor appears to mask or reduce the undesirable flavors. Substantiating evidence for the theory and application of the enzymatic flavor restoration or enhancement concept has been given *(1, 2)*.

The effect of flavor enzymes on a variety of foods has been evaluated by a considerably larger, heterogeneous group of judges which included food experts as well as non-technical people. The following paper summarizes the data obtained from a series of "flavor enzyme demonstration" evaluations.

[a] Presented at the 18th Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 27, 1958.

PREPARATION OF SAMPLES

Commercially processed dehydrated, canned, and frozen foods were used for the test demonstrations whenever available. When commercially processed foods were not available, corresponding fresh foods were processed in the laboratory under simulated commercial conditions.

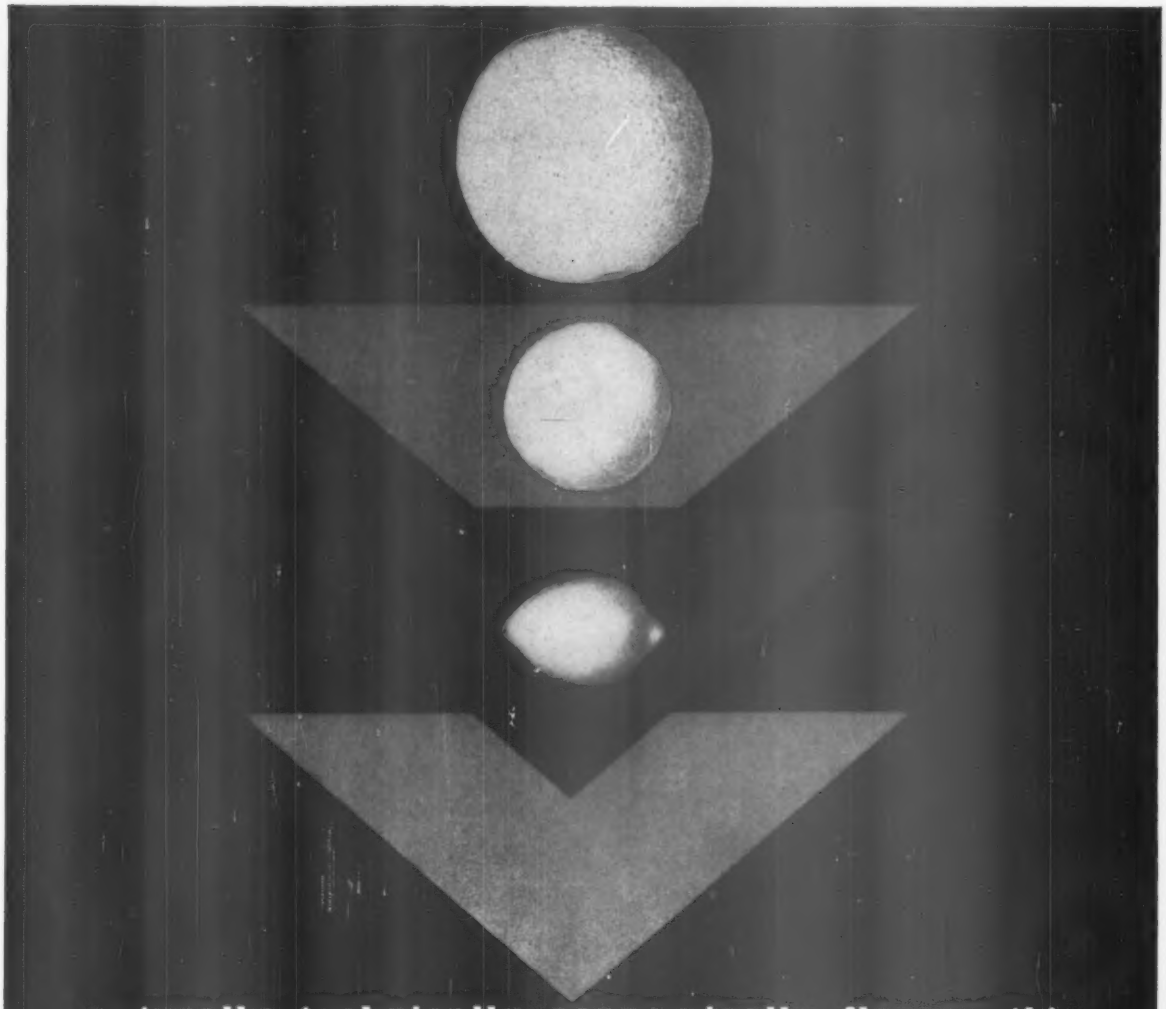
Dehydrated foods were rehydrated with water. In some cases, an extract containing precursor but with no flavor enzymes and almost no flavor, was prepared from the fresh food. This extract was added to the water of rehydration. After standing at room temperature for a few minutes, the samples were divided into two portions, and an appropriate flavor enzyme preparation, prepared as outlined previously *(3)*, was added to one. The other portion was retained as a control. Both portions were then allowed to stand with occasional stirring until tested.

Canned goods were divided into two portions. A suitable flavor enzyme preparation was added to one portion; the other one was left untreated as a control. Both portions were then allowed to stand for a minimum of 15 minutes before testing.

When the food was cooked, baked, or chilled before testing, care was taken to handle the enzyme-treated sample and the control in exactly the same manner and to follow the directions given on the labels of the commercially packaged goods.

In addition to the solid or liquid processed foods, liquid flavor precursor solutions were prepared for evaluation. They were generally made odorless by removing the volatile aroma constituents. These flavor precursor solutions were also presented in pairs. One sample was treated with an appropriate flavor enzyme a few minutes before testing; the other was the untreated control. These flavor precursor solutions were used mainly to demonstrate the regeneration of odor by flavor enzymes.

The following materials were presented among others at the flavor demonstrations: dehydrated cabbage, dehydrated carrots, canned onions, dehydrated watercress, dehydrated horseradish, canned tomato juice, canned peas and carrots, frozen, canned, and powdered orange juice; frozen, bottled, and powdered lemon juice; and cabbage, carrot, orange, watercress, onion, and tomato precursor solutions.



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- **Barley Products**
  - PEARLED BARLEY..7 sieve sizes
  - BARLEY FLOURS (including one in which the enzymes have been inactivated)
- **Corn Products**
  (all electrostatically cleaned—then water washed before milling)
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  - GRITS .....White & Yellow
  - FLOURS.....White & Yellow

TEST CONDITIONS

The food materials to be evaluated were arranged in a row on a long table in an air-conditioned, odor-free test room, reserved for flavor testing. The samples were properly labelled. Judges were requested to test the products with mild flavors first, to avoid rapid onset of fatigue. Ice water and bland crackers were provided to regenerate the sensitivity of the palate.

Solid test foods were placed in covered dishes, and the judges were provided with enough clean spoons and one-ounce glasses so that they had an unused one available for each sample.

Liquid test foods were presented in individual small brandy snifters. Enough snifters were provided so that each judge had a fresh set for tasting.

Liquid flavor precursors, the odors of which were mainly to be evaluated, were also presented in brandy snifters from which aliquots could be removed for tasting if the judge desired. A typical demonstration is pictured in Figure 1.

Individual booths were available to the judges so that they could make their observations without being distracted and without influencing or being influenced by the other judges.

TESTING PROCEDURES

Testing procedures were adapted from the techniques usually used for sensory panel testing, but differed in presentation. Previous results *(1, 2)* had already shown that a trained sensory panel could distinguish enzyme-treated samples from untreated controls. The purpose of the present demonstration tests was to determine the reaction of a heterogeneous, unscreened group to the effect of flavor enzymes.

The judges, who were representatives of many branches of the food industry, participated in the flavor demonstrations in small groups. They were given a short introductory talk to explain the flavor enzyme concept and the testing procedures. Their instructions were to spoon as much as desired of each enzyme-treated test sample and of the corresponding control into clean one-ounce glasses, using clean spoons and to compare the odor and taste of each pair.

In some of the demonstration tests, the enzyme-treated and the control samples were identified; in others, testing was carried out blind. With the horseradish and onions, it was necessary to identify the enzyme-treated samples because of their high flavor level. Generally, their flavor was so strong, that, if evaluated first, they would have dulled the sense of olfaction to a point which would have made subsequent comparisons impossible.

As the results of the blind tests and of previous tests with coded samples were the same as those carried out with labelled samples, the influence of sample bias appears to have been negligible. Most of the people who participated in the demonstrations were representatives from outside industry rather than an internal panel, which should reduce the chances of bias.

The judges were given score sheets (shown in Figure 2) and told to determine first whether they could find a difference in flavor between the treated and the untreated (control) samples and to check the appropriate column. They were then asked to re-examine each pair of test foods to determine which they preferred and to indicate their preference by marking

Figure 2. Typical score sheet.

Food product	Control (no enzyme)	Enzyme-treated	Comments
Dehydrated cabbage			
Canned onions			
Dehydrated carrots			
Canned tomato juice			
Dehydrated watercress			
Frozen orange juice			
Cabbage flavor precursor concentrate			
Onion flavor precursor concentrate			
Carrot flavor precursor concentrate			

0 = no difference
\+ = slight difference
++ = distinct preference
+++ = strong preference
++++ = very strong preference

Name_____

Figure 1. Flavor enzyme demonstration.

their score sheets as follows: + = slight preference, ++ = distinct preference, +++ = strong preference, and ++++ = very strong preference.

No attempt was made to force the participants to evaluate all the samples presented if they preferred not to, but they were urged to do so.

RESULTS AND DISCUSSION

The completed score sheets were collected and tabulated. Table 1 summarizes the results for each of the different foods and flavor precursor solutions presented. The data indicate that adding flavor enzymes had a significant effect on the flavors of the test foods, but that the effect of the flavor enzymes differed markedly, depending on the test materials. Since the supply of test materials was dependent on the amount of work carried out on a particular fruit or vegetable, the number of total judgments for the test products varied rather widely.

Results summarized in Table 1 were converted to the percentages given in Table 2. The data indicate that a difference was found for each test product. Percentage-wise, the difference judgments ranged from 87.5% for canned peas and carrots to 95% and above for the other fruits and vegetables. The preference ratings were more scattered, as Table 2 shows, but the majority of responses indicated a preference for the flavor of the enzyme-treated samples. The individual preference ratings for the enzyme-treated samples ranged from 28.6% for peas and carrots, to 93.3% for dehydrated horseradish, but only two test products scored less than 65%. Preference for the control samples ranged from 3.0% for dehydrated horseradish to 42.8% for canned peas and carrots.

Table 3 summarizes the over-all total of responses obtained. Of the total of 648 responses, 639 indicated a difference between the enzyme-treated sample and the untreated control. In other words, a difference was found in 98.6% of all cases, or in just about every case. The table also shows that the majority of responses (508 or 79.5%) indicated a preference for the flavor of the enzyme-treated samples with the ratings varying, as shown in Table 2, from 28.6% to 93.9%. Although it is debatable whether the data on all the test foods can be pooled because the average

TABLE 1

Demonstration scores for processed foods and flavor precursor solutions

Test product	N[1]	Difference		Preference					
				Control	Enzyme-treated sample				None
		Yes	No		+	++	+++	++++	
Dehydrated cabbage	29	29	0	3	12	9	3	1	1
Dehydrated carrots	59	56	3	4	21	18	3	0	10
Canned onions	68	67	1	5	16	30	9	1	6
Dehydrated watercress	71	71	0	4	13	34	13	4	3
Dehydrated horseradish	66	66	0	2	4	23	12	23	2
Canned tomato juice	17	17	0	2	5	6	3	0	1
Canned peas and carrots	8	7	1	3	1	0	0	1	2
Citrus juice powder[2]	28	27	1	9	8	6	3	1	0
Frozen citrus juice[2]	28	27	1	5	7	12	3	0	0
Canned citrus juice[2]	28	27	1	8	7	11	1	0	0
Cabbage precursor	22	22	0	3	6	3	5	1	4
Carrot precursor	62	61	1	9	20	10	5	1	16
Watercress precursor	66	66	0	9	9	32	8	3	5
Onion precursor	62	62	0	2	14	20	16	5	5
Tomato precursor	15	15	0	3	3	6	0	2	1
Orange precursor [3]	19	19	0	4	8	4	3	0	0

[1] Total judgments.
[2] Includes lemon and orange.
[3] From frozen, canned, and powder.

TABLE 2

Percentage difference and preference scores

Test product	N[1]	Difference (%)		Preference (%)		
		Yes	No	Control	Enzyme-treated	None
Dehydrated cabbage	29	100	0	10.4	86.2	3.4
Dehydrated carrots	59	94.9	5.1	7.1	75.0	17.9
Canned onions	68	98.5	1.5	7.5	83.6	8.9
Dehydrated watercress	71	100	0	5.6	90.1	4.3
Dehydrated horseradish	66	100	0	3.0	93.9	3.1
Canned tomato juice	17	100	0	11.7	82.3	6.0
Canned peas and carrots	8	87.5	12.5	42.8	28.6	28.6
Citrus juice powder[2]	28	96.4	3.6	33.3	66.7	0
Frozen citrus juice[2]	28	96.4	3.6	18.5	81.5	0
Canned citrus juice[2]	28	96.4	3.6	29.6	70.4	0
Cabbage precursor	22	100	0	13.5	68.2	18.3
Carrot precursor	62	98.4	1.6	14.8	59.0	26.2
Watercress precursor	66	100	0	13.6	78.8	7.6
Onion precursor	62	100	0	3.2	88.7	8.1
Tomato precursor	15	100	0	20.0	73.3	6.7
Orange precursor [3]	19	100	0	21.1	78.9	0

[1] Total judgments.
[2] Includes lemon and orange.
[3] From frozen, canned, and powder.

TABLE 3

Summary of demonstration scores

Judgments			Total[1]	Per cent
Difference	Yes		639	98.6
	No		9	1.4
Preference	Control		75	11.7
	Enzyme-treated sample	+	154	24.1
		++	224	35.1
		+++	87	13.6
		++++	43	6.7
	None		56	8.8

[1] Out of a possible 648.

percentage figures computed give much more weight to the test products with large N's and high preference for the enzyme-treated sample, the distribution of the preference ratings for the enzyme-treated products can be calculated. A slight preference was shown in 24.1% of judgments, a distinct preference in 35.1%, a strong preference in 13.6%, and a very strong preference in 6.7% of the judgments.

From the data, it can be concluded that adding flavor enzymes to processed foods and to flavor precursor solutions influences the flavor strongly. The preference ratings show, in addition, a decisive preference for the enzyme-treated samples over the untreated controls. This fact appears to be particularly interesting, because flavor enzymes generally were found to restore the flavor of the fresh food, to which the consumer is not accustomed in the case of several of the test foods used.

The results shown present additional evidence in support of the flavor enzyme concept. A definite improvement in flavor of a variety of processed foods was shown by treatment with flavor enzymes.

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3. *Ibid.*, p. 95.

Fish Flour and Fish Meal by Azeotropic Solvent Processing

(Manuscript received June 3, 1958)

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FOR MANY YEARS, it has been repeatedly emphasized that the fish of the sea are a great source of new wealth. Fish meal and fish oil represent animal feed, human food, and various chemical derivatives of industrial significance *(18)*. International organizations — FAO, UNICEF, and WHO—have reminded us that more than half the world's population is suffering from a severe lack of animal protein. Low cost animal protein from the fish of the sea would appear to be the best hope for remedying this unfortunate situation *(4)*.

Any nation with a shoreline, men, and ships can harvest the fish of the sea. This opportunity could become a powerful impetus for upgrading the economic and political destiny of the "have-not" nations. If translated into an objective, it could have far-reaching consequences in regard to our country's future—and the peace of the world. These are high stakes. What is delaying this great objective?

We need a method to produce standardized, uniform, stable products from fish with the same chemical and biological values as the fish from which these products are derived. We need fish products of low cost to be shipped, stored, and handled in the avenues of commerce in the same way that wheat, corn, rice, sugar and salt are handled. We need a predictable product, the same quality today as it was a year ago when it was made. The sea potential on the basis of its so-called edible catch is not adequate. The edible catch is distributed in the form of fresh, frozen, smoked, dried, salted and canned fish, and, though the total production seems huge, the world's population is increasing faster than edible fish is being made available. A substantial increase in edible fishery products is required. To attain the objective, all fish must be utilized—any species—as long as stable, uniform, standardized products can be obtained. Among such products would be a defatted whole fish meal, and a stabilized fish oil.

CRITERIA OF QUALITY

Fish meals vary from being growth accelerators to actual growth depressants *(11)*, depending on how the fish meal is made and its age *(12, 14)*. Fish meal is now made from fish that are cooked in steam retorts, pressed, and dried. The press water is centrifuged and the oil removed *(18)*. The de-oiled press water may be discarded or it may be evaporated into a thick syrup called fish solubles.

A purchaser of fish meal is likely to be confronted by a number of questions. Is this meal the whole fish? Is it pressed fish without the press water? Is the press water evaporated to make fish solubles and then added back to the pressed fish? Is the fish meal fresh, or is it 6 months old? Has the oil it contains become oxidized and rancid? *(8)*. Has the meal been heated to the point where the protein has been damaged? *(1, 12)*. Has the meal been heated to such a high temperature that the oil has become polymerized and toxic? *(3)*. Will the fish meal produce the same results 6 months after it is mixed as when it was first made?

The variability of the biological value of the protein of fish meals is shown in Table 1. The values vary from poor to excellent *(6)*. Yet, even the good pressed meals have two limitations. First, pressed meals of high biological value may not contain the *quantity* of growth factors that are found in whole fish. If the fish solubles have not been added back to the pressed meal, the meal may have a high biological value for the protein, but it would contain only part of the growth factors *(13)*. Second, the growth depressant effect may not be revealed in a freshly made sample—only in the same sample after rancidity and oxidation of the oil developed in storage *(3, 8, 12)*. Sample "O", VioBin fish meal, shows a high biological value for protein. The table does not show its superiority in growth factors and stability.

TABLE 1
Protein biological value of various fish meals[1]
Egg White Index = 100

No.	% Protein	% Fat	Index	No.	% Protein	% Fat	Index
H	61.9	7.7	63	N	74.1	0.0	88
G	59.4	3.8	71	C	66.0	10.3	91
K	60.2	3.6	73	V	58.4	17.7	97
L	61.9	3.0	74	D	66.7	10.7	98
M	66.6	9.2	79	F	58.5	17.0	99
J	62.2	9.2	84	B	65.0	9.1	104
A	64.4	4.8	85	O	77.2	0.0	108
I	64.7	8.8	87	(VioBin)			

[1] Chick bioassay (1958) by S. W. Hinners *(6)*.

Table 2 gives data on the growth factors as distributed in various parts of fish. It is clear that the purchaser of conventional fish meal, without the solubles, is only getting approximately one-half the response of the unidentified growth factors that are found in whole fish meal.

Data in Table 3 reflect the growth beyond that obtained with adequate purified diets. VioBin whole fish meals are shown to give twice the growth response recorded for good quality pressed meals *(13, 14, 15)*.

The unidentified growth factors are more resistant to destruction than the biologically available protein *(2, 13)*. Therefore, a measurement of high biological value of protein assures the biological value of the growth factors. But it must be emphasized that no matter how good the biological value of the protein, the pressed meal contains only part of the growth factors of the whole fish. The fish solubles contain the other part.

TABLE 2
Unidentified growth factors in various parts of fish

	Gain (g.)	% Increase
Complete basal diet (B)	228	....
B + 5% whole fish	285	25**
B + 5% whole muscle	282	23**
B + 5% fish solubles	255	12*
B + 5% muscle less solubles	258	13*
B + 5% fish viscera	260	14*
B + 5% fish bones	245	7
B + 5% scales	241	5

* Statistically significant at 5% level.
** Statistically significant at 1% level.

[a] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 28, 1958.

TABLE 3

Unidentified fish growth factors in VioBin Meal[1]

	Avg. weight 28 days	% Increase over basal
	(g.)	
Group ration		
Experiment 1		
1. Basal	280*	.....
2. Basal plus 10% fish meal	355	26.8
Experiment 2		
1. Basal	381†	.....
2. Basal plus 10% fish meal	438	15.0
Experiment 3		
1. Basal	365*	.....
2. Basal plus 10% fish meal	425	16.4
Experiment 4		
1. Basal	395*	.....
2. Basal plus 10% fish meal (Exp. 4, Dr. Scott, private communication)	459	16.2

* Avg. of triplicate groups of 10 chicks each.
† Avg. of quadruplicate groups of 10 chicks each.
[1] From Ritchey, Scott, Johnson, *Proc. Soc. Expt. Biol. & Med., 93, 326, 1956.*

NEW APPROACH TO MANUFACTURING FISH MEAL

Our objectives can now be defined. To produce a standardized, stable fish meal equal to the fish from which it is derived, we believe it must be made as follows: (1) The product must be made from the whole fish allowing no division of products into fish meal and fish solubles. (2) Fish must be defatted and dried at temperatures that will not damage the product. (3) Fish meal must be standardized on the basis of biological value. Assaying for amino acids alone is not adequate. The measurement must be an animal assay, accepted by nutritionists as a measurement of protein quality. A biological measurement of the unidentified growth factors should also be obtained.

The whole fish meal must be stable. Defatting fish stabilizes the meal. The oil is stabilized by adding B.H.T. during solvent extraction so that the oil produced is stabilized and the small amount of residual oil in the meal is also stabilized.

The New Bedford Plant. There is now being manufactured at New Bedford, Massachusetts, a standardized, uniform, stable whole fish meal, equal to the fish from which it is derived, in biological value of protein, in unidentified growth factors, at a competitive price with conventional fish meals. The fish meal is biologically assayed and is standardized to have values 20% higher than isolated soy bean protein, using standardized chick methods of measurement *(7, 12)*.

Figure 1 is a flow sheet of the New Bedford plant. The general principles of this process were described previously *(10)*. Actual operating experience shows that the steam consumption and solvent loss are lower than given in that reference.

ADVANTAGES OF THE PROCESS

Some of the advantages of the process are noted. The process is self contained—no odors, no nuisance. It can be set up in coastal areas where fish meal plants are now barred. Defatted fish meal when fed will not impart fishy flavors to eggs, meat, and milk. W. L. Leoschke, in 1957–1958 experiments with mink, has shown that 35% frozen fish can be replaced by its equivalent in VioBin fish meal *(9)*. Defatted whole fish will make possible dry dog and cat foods just as nutritious as fresh fish or meat. Preliminary experiments with feeding fingerlings show that defatted whole fish meal may be the ideal food for which fish hatcheries have been searching.

Nutrition. It is of great interest that this process makes fish flour for human use an immediate reality. Animal experiments revealing the nutritional significance of VioBin fish flour are exhaustively treated by Sure *(16, 17)*. When various cereals are supplemented

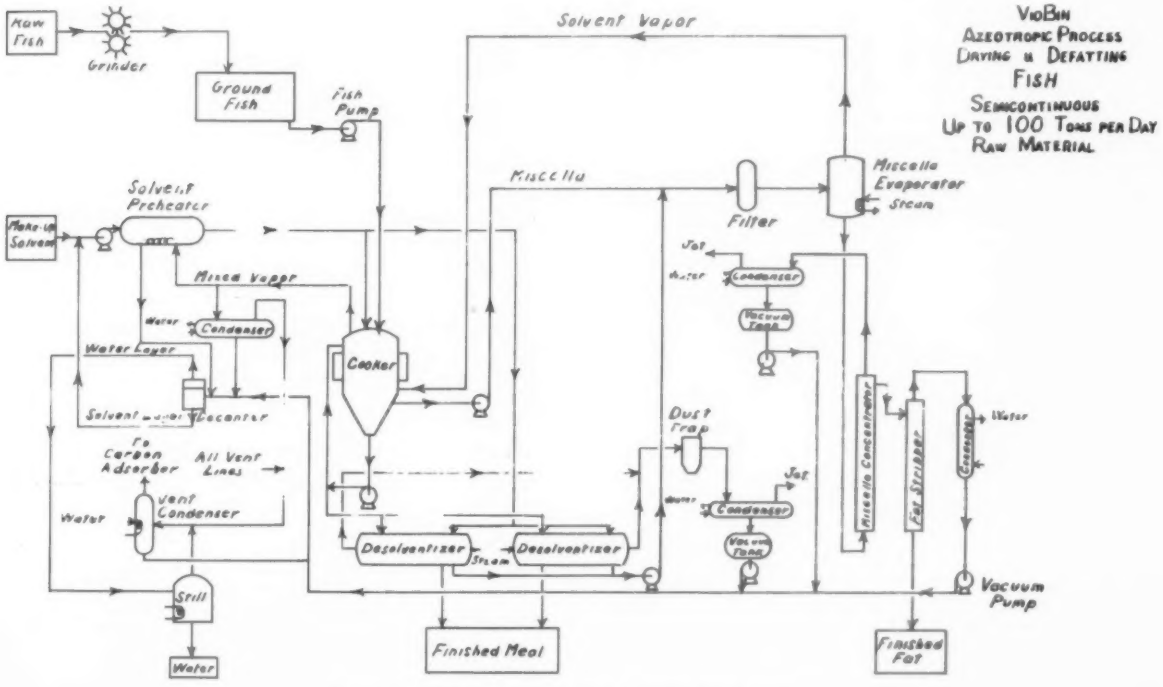

Figure 1. Flow sheet of the New Bedford plant operation.

TABLE 4

Effect of addition of defatted fish flour to whole wheat flour[1]

Type of ration	Amount in ration	Protein	Gains in body weight		Total food intake	Protein intake	P.E.R.[2]
			Actual	Increase			
	%	%	g.	%	g.	g.	
Whole wheat flour	64.0	8.0	65.2	.....	666.2	53.3	1.22
Whole wheat flour	63.0	8.66	104.6	60.4	741.9	64.2	1.63
Defatted fish flour	1.0						
Whole wheat flour	61.0	9.96	142.7	118.8	900.6	89.7	1.59
Defatted fish flour	3.0						
Effect of addition of defatted fish flour to enriched wheat flour[1]							
Milled wheat flour	80.7	8.0	23.4	.....	413.7	33.1	0.71
Milled wheat flour	79.7	8.69	53.9	130.3	554.9	48.1	1.12
Defatted fish flour	1.0						
Milled wheat flour	77.7	10.05	124.0	439.1	755.2	75.4	1.65
Defatted fish flour	3.0						

[1] Experimental period 10 weeks, 12 rats in each group.

[2] Expressed as gains in body weight per gram of protein intake; adapted from Barnett Sure, *J. Nutrition, 61,* 547 (1957); *J. Nutrition, 63,* 409 (1957).

with small amounts of fish flour (1%) remarkable increases in growth result (Table 4). The student of nutrition will agree that it is not likely that 1% of a protein substance, no matter how well balanced the amino acids, could account for such growth. These studies give us a hint that the unidentified growth factors which animal nutritionists have found to be of value for poultry and swine could well have an important effect on humans.

In Mexico, Federico Gomez of the Hospital Infantil, Mexico City *(5)* and his associates have studied VioBin fish flour for 2 years, using rigid methods of measurement such as nitrogen balance studies on children—comparing a corn-bean diet plus 10% fish flour with the same diet plus the nitrogen equivalent in the non-essential amino acid glycine. The influence of VioBin fish flour on rate of growth for many children is charted. The results reveal significant values for fish flour supplementation in overcoming the limitation of corn-bean diets.

Deodorization. Fish flour may be classified with respect to the odor factor as: (1) fishy odor and flavor; (2) partially deodorized; (3) completely deodorized. Various methods for deodorization are used. They usually involve solvents to remove traces of fish oil, and the amines in the fish solids. In South African pilot plant experimentation this is accomplished by a series of washes of the dry pressed fish meal with ethyl alcohol and ethyl acetate. We are exploring much simpler methods. In many instances, complete deodorization is not necessary. Our aim is (1) to prevent reversion of fishy flavor, (2) to deodorize to the point that 10% of the flour will not be detectable when added to any food. Complete deodorization adds to the cost and removes some of the vitamin values of the fish.

Some economic factors. While fish meal, 75% protein, sells for 8½ cents a pound, fish flour, due to more complete solvent extraction and special care dealing with a human food product, would have a price of approximately 12 cents a pound on a contractual basis for large quantities. This means 2½ cents a pound for its fresh fish equivalent. Ninety children each getting 5 g. a day could be protected against kwashiorkor, the protein deficiency disease, with one pound of fish flour (12 cents). The fish flour would have the fish odor and taste. Further treatment for partial deodorization or complete deodorization would add to the cost. But on the basis of American costs, an average price of 15 cents per pound for fish flour is realistic. Obviously, in countries where raw fish, labor, fuel and machinery are less costly, the selling price of fish flour would be even less than 15 cents a pound. Some interesting comparisons with other high protein products are to be found in Table 5.

Considerable work has been done on food mixtures by Werner Jaffe in Venezuela and Federico Gomez in Mexico *(5)*. VioBin fish flour, partially deodorized, when added to soups, cereal foods, bread, biscuits, tortillas, cannot be detected by the consumer.

Lysine source. Fish is an excellent source of lysine. Lysine in the form of deodorized fish flour would cost a fraction of the cost of synthetic lysine, with all the other amino acids and unidentified growth factors "at no extra cost."

Potential as a ship-factory operation. The greatest potential of this or any other solvent extraction

TABLE 5

Some comparisons of interest in an economic appraisal of fish flour

	Fresh egg	Dried egg	Meat	Fresh milk	Dried milk	Fresh fish	Dried and smoked fish	VioBin fish flour
Stability (without refrigeration)	1	4	1	1	7	1	6	10
Availability	1	1	1	1	5	2	3	10
Consumer acceptance	10	10	10	10	10	10	10	10
Quantity of protein per unit cost	1	1	1	1	3	1	3	10

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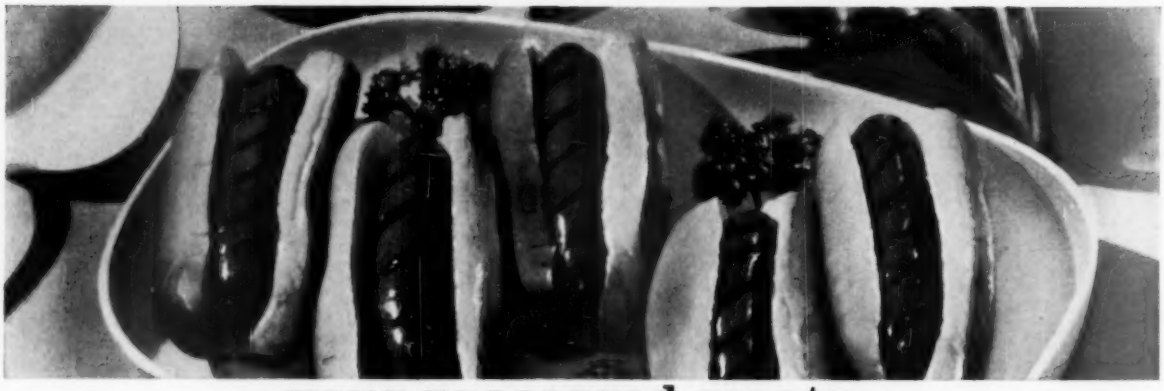

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process for fish is the setting up of such plants on ship. Preliminary study indicates that this is a practical approach to a profitable fishing operation, that would have facilities for freezing edible fish, and solvent extraction of scrap and inedible fish on the same vessel.

A PIONEERING VENTURE

The New Bedford plant, using VioBin processes, is the first fish meal plant of its kind. It opens the door to harvesting the wealth from the sea. Modern chemical engineering, biochemical techniques have been utilized to make a stable, standardized, uniform fish product from almost any species of fish, a product low enough in cost to permit its exploration industrially as well as for food and feed.

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Time-Temperature Tolerance of Frozen Foods. XVI.

Quality Retention of Frozen Green Snap Beans in Retail Packages

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(Manuscript received July 17, 1958)

INDUSTRY ADVISERS suggested that green snap beans should be included at an early stage in the investigations on time-temperature tolerance of frozen foods, because green beans are among the least stable of the popular frozen vegetables under commercial conditions of handling. The objectives and general procedures of the investigation of quality retention in frozen foods were discussed in detail by Van Arsdel *(6)* in the first paper of this series.

In the work reported here, controlled experiments were carried out with commercially packed frozen beans over a −30 to 40° F. temperature range. Sample lots were selected to cover differences in variety, growing area, harvest year, and processing conditions. Variations in blanching conditions were encountered, which affected rate of deterioration. A general description of quality loss of frozen green beans is given, quantitative aspects of deterioration are discussed, and a quality index based on chlorophyll measurement is proposed. Blanching conditions are suggested which will minimize the rate of deterioration in storage.

EXPERIMENTAL PROCEDURES

Materials. Observations were made of raw material handling and processing at the plant in order to obtain commercial products of desired quality and known history. Lots ranging from 8 to 110 dozen retail-sized packages (generally 10 oz.) were taken consecutively from production lines to minimize variability among packages. Shipments were made by rail express under dry ice refrigeration in frozen food shippers and were re-iced enroute on trans-continental trips. Nearby procurements were similarly packed with dry ice and transported by motor vehicle. On receipt at the laboratory, lots were held at −20 or −30° F. until transferred to controlled elevated storage temperature conditions.

Nineteen lots of green beans were obtained from 12 different packers during 5 harvest years (1952 through 1956) from 6 important producing areas (Western Oregon, Western Washington, Central and Southern California, Tennessee, and the Eastern Seaboard). Varieties tested were Blue Lake (a pole type), Top Crop, Tendergreen, and Tenderlong (bush types). Thirteen of the lots were one-inch cut; 3 were one-and-a-half-inch cut, and 3 were French cut.

On receipt all lots were analyzed for peroxidase activity, reduced ascorbic acid content, and percentage conversion of chlorophyll to pheophytin (C_1). After the first year, reflectance color data were also obtained by the Hunter Color and Color Difference Meter (HCM).

Considerable variability existed among lots. The degree of uniformity within lots also varied. The effect of the latter factor was minimized by averaging the results of 4 to 6 replications in the later phases of the investigation.

One small lot of 16 dozen packages (Lot 9) showed peroxidase activity. This test indicated that beans in different packages were slightly under-, borderline-, or over-blanched with respect to enzyme inactivation. Serious non-uniformity of texture from package to package was noted. Packages of undesirably tough beans had residual peroxidase activity; in these instances, an undesirable tough texture appeared to be related to under-blanching. Storage characteristics of this lot fell within the range of other lots observed and therefore it was included in the study.

In the 19 lots of beans as received, reduced ascorbic acid, percentage chlorophyll retention, and measurement "a", by HCM, varied over a wide range as seen in Table 1. An apparent correlation was observed between amount of chlorophyll retained and conditions of blanching (also summarized in Table 1). Other studies in this laboratory on experimental packs have confirmed this correlation. Results are described elsewhere by Dietrich *et al. (2)*, who concluded that relatively low-temperature and long-duration blanching of green beans results in greater chlorophyll loss than high-temperature, short-duration blanching when the beans are blanched to about the same degree of peroxidase inactivation.[b]

Differences observed in reduced ascorbic acid content probably reflect the result of normal variations in the vegetable as grown. These differences appear to be greater than can be attributed to processing and handling prior to procurement. HCM "a" values are correlated with chlorophyll values $r = 0.79$).

Experimental procedures. Peroxidase activity was determined by the method of Masure and Campbell *(4)*. Reduced ascorbic acid, chlorophyll conversion to pheophytin, and reflectance measurement of color were determined by procedures described by Dietrich *et al. (1)*. Analyses for ascorbic acid and chlorophyll were generally made on separate halves of the same package. Material was held at −20 or −30° F. after storage at higher temperatures until analyzed or appraised.

Chlorophyll conversion to pheophytin is reported as percentage chlorophyll retention. This is calculated by subtracting the total conversion percentage from 100. In all instances the total includes both the losses due to processing, reflected in C_1, and those due to storage deterioration.

Subjective evaluations were made by panels consisting of 10 selected and trained judges whose performances were checked for uniformity of sensitivity and reliability throughout the investigation. They appraised color of thawed uncooked green beans and flavor of the cooked vegetable. Forty judgments were made for flavor and 10 to 20 for color. Texture evaluations were run for one year and then discontinued (except for Lot 9) because important textural changes

[a] Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, 800 Buchanan Street, Albany 10, Calif.

[b] In some commercial operations, blanching at relatively low temperatures (185 to 190° F.) was observed. Some processors believe that such blanching conditions minimize the tendency of product to slough its outer skin after freezing and stabilize the texture throughout subsequent processing and storage. However, beans can be blanched above 200° F. without skin-sloughing if the blanching time is held to the minimum necessary for inactivation of peroxidase *(2)*.

TABLE 1

Identification and description of lots

Lot no.	Harvest year	Variety[1]	Growing area[2]	Blanching conditions			C_1[4]	Ascorbic acid	HCM "a" value
				Temp.	Media[3]	Time			
				(°F.)		(min.)	(%)	(mg./100 g.)	(units)
1	1952	TC	ES	212	S	2¼	81.2	6.2	15.7
2	1952	BL	O	212	W	1–2	93.1	7.4	16.3
3	1953	TC	ES	212	S	2¼	80.0	6.2	14.4
4	1953	BL	O	212	W	1	95.2	7.0	16.2
5	1954	TG	Ten	205	W	2	85.9	10.2	15.2
6	1954	BL	So	190	S	5	73.8	6.8	10.4
7	1955	TL	Ten	205	W	2	86.0	10.8	14.5
8	1955	BL	C	180	S	2			
				195	S	2	72.7	7.0	11.6
9	1955	BL	So	.....	S	....	84.0	9.5	12.5
10	1956	TC	ES	.....	....	....	77.0	3.5	14.2
11	1956	BL	W	202	W	2¼	75.2	10.0	12.6
12	1956	BL	O	207	W	1⅜	91.4	6.5	13.8
13	1956	BL	C	200–204	S	1½	89.5	4.4	15.6
14	1956	BL	C	200–204	S	1½	89.2	4.4	15.2
15	1956	BL	C	197–207	S	4	77.8	7.4	13.3
16	1956	BL	C	>200	S	1¾	86.6	10.4	14.0
17	1955	BL[5]	C	180	S	2			
				195	S	2	66.9	10.5	12.2
18	1956	BL[5]	W	195–200	S	1⅞	85.8	13.4	15.3
19	1956	BL[5]	C	200–204	S	1½	85.7	3.8	15.0

[1] TC is Top Crop; BL is Blue Lake; TG is Tendergreen; and TL is Tenderlong.
[2] ES is Eastern Seaboard; O is Western Oregon; Ten is Tennessee; So is Southe n Ca'ifornia; W is Western Washington; and C is Central California.
[3] S represents steam blanching and W represents water blanching.
[4] Initial level of percentage chlorophyll retention.
[5] French cut.

were found not to be related to storage conditions for adequately blanched beans.

Appraisals were made by ranking a series of samples from the same lot, which had been stored for several time intervals under a given temperature condition. Control samples held continuously at −20 or −30° F. represented zero time. Three stored samples and the control were used in each replication for flavor and up to 6 samples for color.

Rank data from each storage temperature series were treated in two ways. First, in order to ascertain the shortest storage time that resulted in a detectable amount of deterioration, data representing samples of each storage time were compared with the control and a percentage concurrence of difference judgments were calculated. Examples of paired samples for difference judgment would be control (−20° F.) and a 7-day sample held at 25° F.; control and a 14-day sample; control and a 21-day sample, etc. Then the shortest time that resulted in a 75% or greater concurrence of judgment was considered to be the time of first detectable deterioration. Second, in order to correlate subjective evaluation data with the amount of difference in objectively measured criteria, percentage concurrence of judgments of paired samples of adjoining storage periods were used. For example, a control sample would be compared with a 7-day sample; a 7- day with a 14-day; a 14-day with a 21-day, etc.

Further subjective evaluations of color deterioration were obtained by arranging for grading sessions with representatives of industry, selected because of their professional concern with quality standards of frozen foods in commercial markets—quality control men, buyers, etc. Opinions were based on appearance of thawed beans, each sample being scored in one of three categories: 1, acceptable and high quality; 2, acceptable but not high quality; and 3, sufficiently poor to cause consumer complaint. For these panels, 4 to 6 samples from a given lot held for different storage times at a specific temperature were judged as a series in comparison with each other and a −20 or −30° F. control.

Lots 1 to 6 were stored at intervals in the range −10 to 40° F. and also under several conditions of cyclic temperature fluctuations. Lots 7 and 8 were exposed to temperatures of simulated market distribution. Lots 7 to 16 were used to verify results of previous lots. Three lots of French-cut beans, 17 to 19, were compared with regular cuts at 0 and 20° F.

RESULTS

Quality deterioration at constant temperatures. Color deterioration of frozen green beans caused by holding under adverse conditions can be described as a preliminary change from bright natural green to greyish green and later to an olive green. In the extreme, beans change to a brownish green. Color changes could be detected early in beans stored under poor conditions. However, the detection of off flavor required longer periods.

Examples of average ranks for color and flavor of samples of Lots 3 to 16 stored for different intervals at 20° F. are listed in Table 2. They indicate that with the times selected the panel consistently detected differences in color between samples (average ranks increase with length of storage) but distinguished flavor differences only after greater intervals.

TABLE 2

Average color and flavor ranks for beans stored at 20° F.

Lot no.	Time in days							
	0[1]	3½	7	14	21	28	42	56
				Color				
3	1.1	....	2.5**	2.4	4.3	4.7	6.0	7.0
4	1.3	....	1.9*	3.2	4.1	4.6	5.9	7.0
5	1.6	....	1.7	2.9*	3.9	4.9	6.0	7.0
6	1.0	....	2.0*	3.0	4.2	4.8	6.0	7.0
7	1.3	....	1.9*	2.9	3.9	5.0	6.1	6.9
8	1.2	....	1.9*	2.8	....	4.1	5.7	5.2
9	1.3	....	1.9*	2.8	4.4	4.6	6.2	6.8
10	1.4	1.7	2.8*	4.0	5.1	6.1	6.9	....
11	1.2	2.2*	2.7	3.9	5.1	5.9	7.0	....
12	1.1	1.9*	3.0	4.0	5.0	6.0	7.0	....
13	1.5	2.1	2.4*	4.1	4.9	6.0	7.0	....
14	1.4	2.0	2.7*	4.0	5.0	6.0	7.0	....
15	1.6	1.6	2.8*	4.0	5.2	5.8	7.0	....
16	1.2	2.1*	2.9	3.8	5.0	6.0	7.0	....
				Flavor				
3	1.6	....	....	....	....	2.7*	2.8	2.9
4	1.6	....	....	....	....	2.2	3.0*	3.2
5	1.4	....	....	2.1*	....	3.0	3.5	....
6	1.9	....	....	2.0	....	2.5	3.6*	....
7	1.5	....	2.1*	2.9	....	3.5	....	....
8	1.6	....	2.2	2.8*	....	3.3	....	....
9	1.5	....	2.2	2.8*	....	3.4	....	....
10	2.1	....	....	2.3	....	2.7	2.9*	....
11	2.0	....	....	2.2	....	2.8	3.0*	....
12	1.8	....	....	2.0	....	2.9*	3.3	....
13	1.7	....	....	2.7*	....	2.8	2.9	....
14	2.0	....	....	2.1	....	2.8	3.1*	....
15	1.6	....	....	2.0	....	2.9*	3.6	....
16	2.0	....	....	2.4	....	2.4	3.2*	....

[1] 0 days assigned to control sample stored at −20° F.
[2] Asterisks indicate first significant difference: 75% or greater concurrence of judgments for the comparison of the control with the stored sample.

The rate of deterioration cannot be precisely determined from such data. However, these and many other data of this type do indicate that the color began to change in the earliest intervals and continued to deteriorate at an observable rate throughout each test. Flavor change was not great but was usually detectable by the end of each study, which was generally continued to a point where color was believed to be unacceptable.

A general relationship of rate of deterioration can be expressed as the number of days at a particular temperature where 75% of the panel concurred that there was a difference between the control and the stored sample. Average periods that resulted in a detectable difference from control samples for Lots 3, 4, 5, and 6, stored at five temperatures, are shown in Table 3. These averages were obtained by calculating a regression of days to a detectable difference (expressed as a logarithm) on storage temperature.

TABLE 3

Influence of temperature on flavor and color deterioration

	Number of days to a first detectable difference[1]	
Storage temp. ° F.	Color	Flavor
0	101	296
10	28	94
15	15	53
20	8	30
25	4	17

[1] Regression of log days to a first detectable difference on storage temperature for Lots 3, 4, 5 and 6.

Data for 30° F. were not used in this regression calculation because a consistent departure of the objective measurements of deterioration at this temperature indicated that the relationship did not continue much beyond 25° F.

Slopes of the flavor and color regression lines were −.0497 and −.0551, respectively, (log days per degree F.), with standard errors of estimate of .2037 and .2117. The scatter of individual points indicated by the standard errors of estimate is such as would occur with a variation of about ±4° F. of storage temperature.

This error has two major sources in addition to the variability of judges' decisions: 1) the variability between lots of beans in this study is large and storage deterioration rates were not the same for different lots, and 2) a variability exists that is related to the experimental design which did not provide sufficient time intervals to define more precisely the point of 75% concurrence of judgments.

Data in Table 3 show that flavor and color deterioration rates are exponential—increasing about two-fold with each 5° F. increase in temperature in the range of 0 to 25° F. In general, a flavor difference from a control sample could be detected in a sample stored about 10 months at 0° F., and in about 17 days at 25° F. A color change could be detected in a third to a quarter of the time required for flavor change.

For 10 other lots (7 to 16) stored at 20° F., the average number of days to the first detectable flavor and color difference was 27 and 6, respectively. These values are in satisfactory agreement with the 30- and 8-day regression values given in Table 3.

Objective measurements of quality difference provided a more precise description of deterioration of stored frozen green beans. When objective data from these same 4 lots were statistically treated in a way similar to that described above for the color and flavor deterioration, an effect equivalent to a variation of ±2° F. was found by calculating the standard error of estimate for measured rate of change with storage temperature of percentage chlorophyll retention, reduced ascorbic acid, and HCM "a" value. Even greater precision was obtained for individual lots when lot-to-lot variability was taken into account as described below in connection with measurements of the percentage retention of chlorophyll.

Because of the mass of objective data obtained in this investigation (about 13,000 individual packages of beans were used), statistical compilations are used for the objective data on quality deterioration, rather than tabulations of observed data, for development of useful information.

For example, observed data on the retention of chlorophyll and reduced ascorbic acid for sub-lots of Lot 1, stored at 10° F. intervals from −10 to 30° F. and cyclic fluctuations of temperatures between −10 and 10° F., and between 10 and 30° F. are plotted in Figure 1. In addition, calculated regression lines of log percentage chlorophyll retention on time and concentration of reduced ascorbic acid on time are drawn. It is seen that the observed values did not deviate widely from the straight lines. Lines for temperatures below 10° F. include observed values up to 365 days.

The regression lines of Figure 1 can be expressed by the equation:

$$\text{Log } C = \log C_r - Sd, \qquad (1)$$

where C = percentage chlorophyll retention after d days,

C_r = regression value of percentage chlorophyll retention at zero time, and

S = the change in regression value of log C per day for a specific storage temperature of a given lot of frozen beans (the direction of the slope, which is negative, is taken into account by the minus sign in Equation 1).

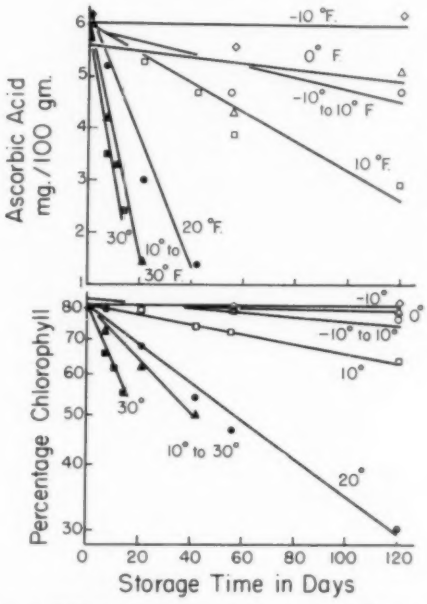

Figure 1. Effect of storage conditions on retention of chlorophyll and reduced ascorbic acid. Chlorophyll data are plotted as a semi-logarithmic graph.

In Figure 1, calculated values for S were 0.042 x 10^{-2} for 10° F. storage; 0.245 x 10^{-2} for 0° F. storage; 0.450 x 10^{-2} for cyclic fluctuation of temperature between −10 and 10° F. etc. Calculations based on such regression coefficients can be used to elicit relationships among the several quality attributes studied, the effect of time and temperature on quality deterioration, and a general definition of deterioration of frozen green beans.

Table 4 is a compilation of S values for Lots 1 to 6 for six storage temperatures. Some differences between lots are obvious in spite of occasional reversals. Thus, Lots 2 and 4 appear to have generally smaller slopes (slower deterioration) than Lots 1, 3, 5, and 6. Lot 6 appears to be generally higher in deterioration rate than all the others.

TABLE 4

Rates of chlorophyll deterioration, S, in the range of 0 to 30° F.[1]

Lot No.	Storage temperature (° F.)					
	0	10	15	20	25	30
1	.245	.951	1.926	3.698	8.313	12.005
2	.185	.526	1.114	1.830	3.769	6.638
3	.190	1.052	1.818	4.110	10.540	15.923
4	.126	.562	1.248	2.434	5.008	8.130
5	.111	.753	2.088	3.219	6.000	12.753
6	.170	1.172	2.311	5.931	11.705	15.211

[1] Rates are given as slopes x 1000 of the calculated regression lines, as in Figure 1, of log percentage chlorophyll retention on storage time in days.

Considering the possible sources of variation among lots, variety did not appear to be an important cause; the two slowest to deteriorate (Lots 2 and 4) and the fastest (Lot 6) were all of the Blue Lake variety. Two lots of Top Crop (Lots 1 and 3) and one of Tendergreen (Lot 5) were intermediate. Lots 1 and 3, 2 and 4 were paired as a direct check on harvest year difference when other factors (i.e., growing area, variety, and processor) were the same. The paired lots showed a similarity in deterioration rates that indicated no major differences between these harvest years for two areas, Eastern seaboard and Western Oregon. Lots 1 and 5 had similar deterioration rates but were of different varieties of bush type beans from different areas and harvest years.

Differences among processors, or more correctly processes, appeared to be a source of the differences among lots. Inspection of Table 1 brings out the fact that Lots 2 and 4 had a high-temperature, short-time blanch and a high retention of chlorophyll (C_i) compared to Lot 6 which had a low temperature-long time blanch and a low retention of chlorophyll.

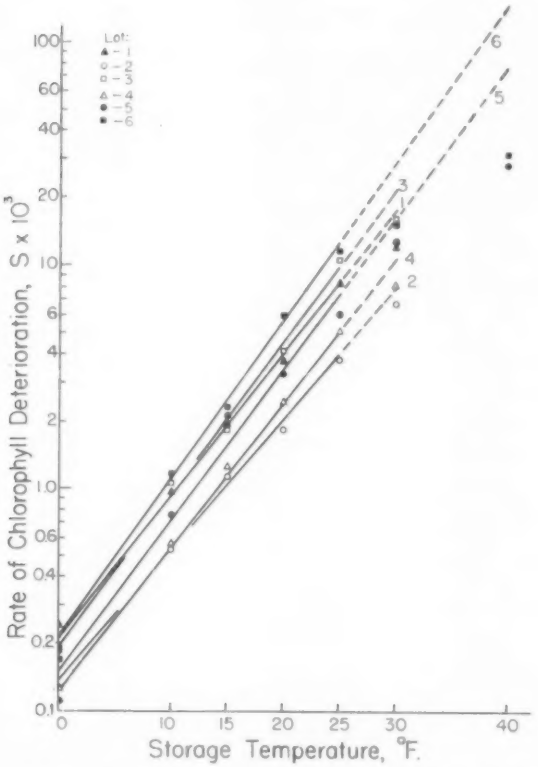

Figure 2. Effect of temperature on the rate of chlorophyll deterioration. Points are observed values S; lines are drawn from regression values, S', and plotted as a semi-logarithmic graph.

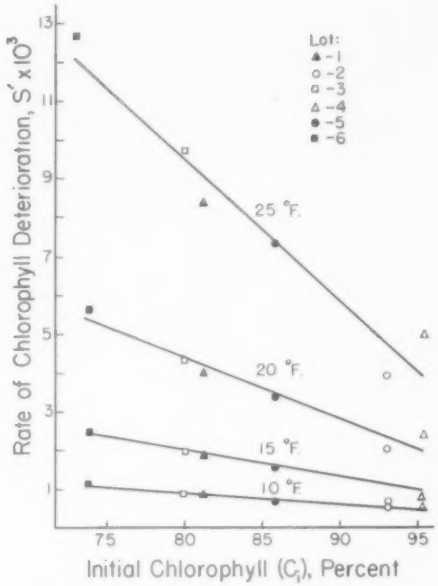

Figure 3. Effect of initial chlorophyll level, C_i, on rate of chlorophyll deterioration.

Data in Tables 1 and 4 were used as the basis of a description of deterioration of stored frozen beans. S values of Table 4 were used to calculate the regression of slope (S, expressed as a logarithm) on storage temperature, over the 0 to 25° F. range. Values of log S are plotted against storage temperature in Figure 2 along with calculated lines.

An extension of the regression lines beyond 25° F. clearly indicated the rate of deterioration at 30° F. was less than would be expected from the relationships drawn between storage temperature and rate of deterioration in the lower range. Data were available for Lots 5 and 6 at 40° F. storage and these also fell below the extrapolated lines for these lots. This investigation does not provide a reason for the break in the relationship between temperature and reaction rate involved. It is suggested that the change in state, from frozen to thawed condition, that occurs near 28° F. may be in some way responsible. For example, reactant concentration in eutectic solution below the freezing point may be greatly diluted by thawing.

Calculated regression values in Figure 2 provide a general estimate of deterioration rate for chlorophyll in these lots of frozen beans. The antilog of these values is identified as S' and may be substituted in Equation 1 to estimate the chlorophyll retention of a sample stored at any temperature.

Regression lines of Figure 2 are substantially parallel, indicating a similar temperature coefficient for all lots. However, rates for different lots at a given temperature are seen to differ. An adequate description of quality deterioration of frozen beans requires a valid explanation of such differences. A comparison of deterioration rate with the level of chlorophyll existing at the initiation of the storage experiments (C_i in Table 1) suggests that the method of processing is an important factor that influences the stability of the frozen product.

Values of S' (antilog of points on lines in Figure 2) were plotted against C_i in Figure 3 for each of the 6 lots for temperatures 10, 15, 20 and 25° F. The existence of a straight line relationship between C_i and chlorophyll deterioration was apparent and regression lines were calculated and drawn. These served as the basis for an empirical equation relating rate of chlorophyll deterioration of stored frozen beans to storage temperature and C_i. The relationship was reduced to the following exponential equation:

$$S'' = (119.0 - 0.55T - C_i)e^{(0.178T-12.21)} \quad (2)$$

where S'' = slope of the regression of log percentage chlorophyll retention on time, as the change in log C per day,

T = storage temperature (° F.), and

C_i = initial percentage chlorophyll retention.

This equation should not be used for extrapolation beyond the region where experimental data are shown to be well represented by the linear regression lines—that is, for values of T between 0 and 25° F., and for values of C_i above 74%. By substitution of S'' and C_i for S and C_r Equation 1 can be modified to predict the chlorophyll retention for any stored lot of beans for which C_i and the storage temperature are known.

It is evident from Equation 2 that the higher the initial chlorophyll retention, the slower was the rate of chlorophyll deterioration in the subsequent storage at any given temperature. This could not be a direct causal relationship because that would lead one to expect that as the chlorophyll percentage decreased during storage of any lot, the rate of further loss would *increase*. As was seen in Figure 1, and as expressed in Equation 1, the rate of deterioration for any lot at a given temperature was constant in the log relationship.

As noted above, the value of the initial chlorophyll retention for any lot appeared to be strongly influenced by the conditions that had been used to blanch the material adequately with respect to peroxidase enzyme. It can only be surmised at the present time that the differences in blanching conditions were also responsible for the observed differences in chlorophyll deterioration rates. C_i is offered as providing an empirical fitness, and as being useful in the absence of specific knowledge to relate blanching conditions directly to deterioration rate.

In addition to the 30 storage studies upon which Equation 2 was based (Lots 1 to 6; temperatures 0, 10, 15, 20, and 25° F.), 27 other storage studies at constant temperatures were run. Eight of these studies were at 30 or 40° F. and did not conform to the general pattern of chlorophyll deterioration, as discussed above. The remaining 19 studies serve as a basis for comparison of the observed values of chlorophyll deterioration with those calculated by Equation 1 (where S'' for each lot of beans and storage temperature is calculated by Equation 2 and this rate value and C_i are substituted into Equation 1). Table 5 lists observed and calculated values of chlorophyll retention at intervals of storage where observed values indicated a considerable degree of deterioration. In view of the dissimilarity between lots, the differences between the observed and calculated chlorophyll retention are small in relation to differences that were detected by the trained panel. Lots 8 and 17, with C_i of 72.7 and 66.9, are below the range of expected valid results; and Lot 11, with C_i of 75.2, is on the lower limit. These 3 lots account for the 3 largest negative differences in this comparison. A further comparison is provided by the calculated number of days required to reach the observed chlorophyll retention, based on S'' values.

From these data it may be concluded that Equation 2 does provide a general description of chlorophyll deterioration as related to storage temperature and C_i over a broad range of variability among lots of frozen green beans.

Because the French-cut beans did not differ substantially in regard to deterioration during storage, data from these lots have been included without differentiation from the regular cut frozen beans.

The ascorbic acid loss for frozen beans, as shown for Lot 1 in Figure 1, and the changes in HCM "a" values followed a course of deterioration similar to that of chlorophyll. However, analyses for reduced ascorbic acid and HCM "a" readings were not sufficiently reproducible from package to package to provide as accurate a measurement of quality as did the chlorophyll determination.

Samples from Lots 10 to 19, except 17, were stored at 20° F. for 7 intervals of time between 0 and 42 days. Four replicate determinations each from a different package were used for chlorophyll retention and reduced ascorbic acid measurement. Two packages were used for HCM "a" measurement. Slopes of regression of deterioration on time were calculated on averages of replications. Log percentage chlorophyll retention, log HCM "a" value, and concentration of reduced ascorbic acid were the parameters used. To obtain an estimate of variability of the methods of measurement, standard errors of these slopes were calculated and expressed as a percentage of the slope. For the chlorophyll measurement the standard error ranged from 1.7 to 6.8% with an average of 4.0; reduced ascorbic acid, 4.4 to 12.1, average of 7.6; HCM "a" value, 3.2 to 11.5, average of 7.2.

These larger errors in ascorbic acid and HCM "a" values account for occasional observations where ascorbic acid or HCM "a" appeared to increase with storage time over short intervals. Only very rarely, and in no important degree, were such reversals found in the chlorophyll retention data.

There was a tendency for the rate of ascorbic acid loss to be higher for lots with more ascorbic acid but this effect could not be closely defined. It appeared that change in chlorophyll

TABLE 5

Comparison of observed and calculated chlorophyll retention and storage time

Lot No.	Storage condition		Chlorophyll retention [1]			Calculated storage time
	Temp.	Time	Observed	Calculated	Difference	
	(° F.)	(days)	(%)	(%)	(%)	(days)
1	−10	365	78.5	78.6	+0.1	374
2	−10	365	91.2	90.9	−0.3	318
4	0	365	73.7	74.9	+1.2	408
8	0	365	62.2	59.9	−2.3	293
9	0	365	74.0	72.6	−1.4	317
17	0	240	59.6	58.0	−1.6	194
5	5	365	61.3	63.5	+2.2	407
6	5	365	42.2	44.9	+2.7	411
17	10	240	40.6	32.4	−8.2	166
7	20	42	61.0	61.4	+0.4	43
8	20	42	52.6	42.3	−10.3	25
9	20	42	57.4	58.2	+0.8	43
10	20	42	52.5	47.9	−4.6	34
11	20	42	52.6	45.5	−7.1	30
12	20	42	64.2	70.8	+6.6	58
13	20	42	67.0	67.4	+0.4	43
14	20	42	67.1	66.8	−0.3	42
15	20	42	51.1	49.0	−2.1	38
16	20	42	58.2	62.4	+4.2	51
17	20	42	41.0	35.6	−5.4	33
18	20	42	64.9	61.0	−3.9	34
19	20	42	62.4	60.9	−1.5	39
7–19 Comparative example:	20	42	av. 57.8	56.1	−1.6	39.5
			range 67.1	66.8	−10.3	58
			range 41.0	35.6	+6.6	25

[1] Values reflect total of all chlorophyll conversion: processing and storage.

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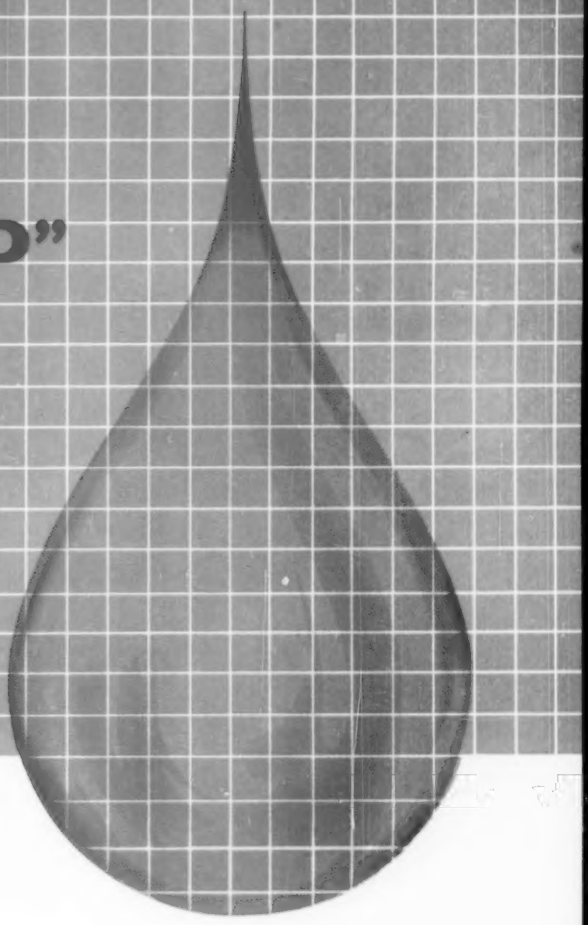

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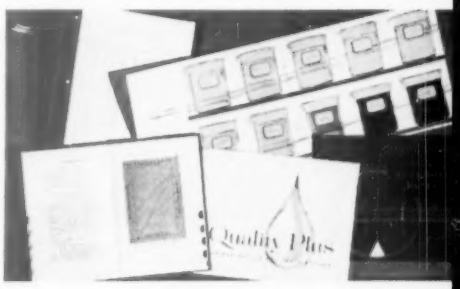

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was not influenced by the same factors as the deterioration of ascorbic acid. However, for individual lots of beans, ascorbic acid provided a good measure of relative quality deterioration.

Subjective evaluations of color and flavor differences between individual samples (same lot, same storage temperature, different intervals of storage) were compared with objective measurements of chlorophyll retention, reduced ascorbic acid, and HCM "a" value.

In Table 6 are listed average differences between samples in the objectively measured quality factors, with the percentages of concurrent judgments of color and flavor differences between the same samples. These data may be interpreted as follows: When about 4% difference in chlorophyll level existed between samples, the change in color was sufficiently large that approximately 85% of the panel detected the difference. When 3.5% difference or less in chlorophyll levels existed between samples, concurrence of difference judgments ranged from 50 to 84%.

TABLE 6

Comparison of objective measurements of quality change with evaluations of difference in color and flavor between samples[1]

Concurrence of judgments indicating difference	Mean difference in chlorophyll retention	Mean difference in ascorbic acid content	Mean difference in HCM "a" value
		Color	
(%)	*(%)*	*(mg./100 g.)*	*(units)*
Less than 55	3.5	.8	.6
55 to 64	2.5	.5	.5
65 to 74	3.3	.6	.6
75 to 84	3.5	.7	.5
85 to 94	4.6	1.1	.9
More than 94	6.4	1.1	1.1
		Flavor	
Less than 55	7.4	1.2	1.4
55 to 64	7.3	1.3	1.3
65 to 74	10.0	1.8	1.6
75 to 84	13.5	2.5	2.5
85 to 94	20.3	3.6	3.5
More than 94	26.2	4.4	4.6

[1] Data summarize results from all lots—however, the comparisons were all made within lots.

Similarly, color difference judgments approached this degree of significance between samples having about 0.9 mg. per 100 g. difference in ascorbic acid content and 0.7 units difference in HCM "a" value. These levels of difference were small relative to experimental error and sample to sample variability. For this reason it would not be expected that these measurements would be so descriptive of color change as is the measurement of chlorophyll change. They do, however, on the basis of average data over the breadth of this investigation show a relationship to subjective evaluation that is quite regular.

In order to detect a flavor difference, more deterioration was required than for color. Data in Table 6 indicate nearly a four-fold increase in values for the three objective measurements to obtain the 85% concurrence.

It should be emphasized that these comparisons have been drawn between samples of a given series from one lot, not between samples of different lots. However, comparison of samples from different lots would have been valuable in developing an absolute correlation of subjective with objective measurement of quality. An inherent difficulty in subjective appraisals between lots is that factors other than color or flavor may affect judgments. For example, if a lot of one-inch cut green beans were compared with another lot which was French-cut, judgments would not successfully be confined to color difference. More subtle variations in appearance and flavor existed between most or all of the lots tested and across-lot evaluation of color or flavor differences could have been only of limited value.

Quality appraisal by industry panel. On three occasions industry panels scored samples for color and appearance. Data for 6 different lots are presented in Table 7 as percentage of judgments scored as described in the section on Experimental Procedures. C_1 and a calculated regression value for the percentage of chlorophyll retention of each stored sample is tabulated as a standard for comparison. For each lot, as the chlorophyll deteriorated a lower percentage of "1" scores was given and a higher percentage of "3" scores.

It might be suggested that initial high quality of frozen beans no longer exists after a storage experience that results in a substantial percentage of the panel refusing to score the sample "1". Furthermore, as a substantial number of judgments suggest that consumer complaints would be received, a low level of marketing quality must have been reached.

Attempts to establish, by use of the data of Table 7, an absolute relationship of panel judgment to the amount of chlorophyll retained were not very successful. However, for Lots 1, 5, and 7 a close relationship existed as shown in Figure 4, in which the percentage of panel scores for high quality are plotted against the percentage of chlorophyll retained. A remarkable similarity is apparent among these 3 lots, which represent 3 varieties, 2 growing areas, 2 packers, and 3 harvest years and were judged by 3 separate panels of industry representatives on 3 occasions over a 3½-year period.

When chlorophyll retention was in the range of 80 to 85%, nearly all of the judgments indicated that quality was high and when it was about 75%, a majority of the panel members would judge the product as no longer of the highest quality.

These 3 lots, all bush-type varieties, had initial chlorophyll levels in the narrow range of 81 to 86%. The other 3 lots, which did not conform to the general relationship stated above were all of the Blue Lake variety and were quite dissimilar as to initial chlorophyll level.

Samples from individual lots were presented to the panel as a series where the control sample (stored at −20° F.) tended

TABLE 7

Industry panel judgments of acceptability

Lot No.	Storage conditions		Percentage of judgments[1] Score			Chlorophyll retention
	Time	Temp.	1	2	3	
	(days)	*(° F.)*				*(%)*
1[2]	0	−20	67	33	0	84.2
	42	10	46	46	8	74.9
	120	10	0	86	14	63.1
	56	20	0	0	100	49.8
2[2]	0	−20	100	0	0	93.1
	42	10	42	58	0	87.3
	120	10	14	64	22	79.4
	56	20	0	50	50	71.7
5[3]	0	−20	90	8	2	85.9
	14	20	63	37	0	77.2
	28	20	25	73	2	69.6
	42	20	2	86	12	62.7
	56	20	8	61	31	56.5
6[3]	0	−20	39	55	6	73.8
	14	20	20	70	10	60.3
	28	20	8	63	29	49.8
	42	20	2	37	61	41.1
	56	20	0	18	82	34.0
7[4]	0	−20	100	0	0	86.0
	7	20	100	0	0	80.0
	14	20	55	45	0	75.4
	21	20	27	73	0	71.1
	28	20	9	73	18	67.0
	42	20	0	45	55	59.5
8[4]	0	−20	100	0	0	72.7
	7	20	70	30	0	68.1
	14	20	30	70	0	64.4
	21	20	9	73	18	60.9
	28	20	9	55	36	57.5
	42	20	0	36	64	51.4

[1] Score 1 = acceptable and high quality; Score 2 = acceptable but not high quality; Score 3 = sufficiently poor to cause consumer complaint.

[2] Panel held January, 1954.

[3] Panel held March, 1955.

[4] Panel held August, 1956.

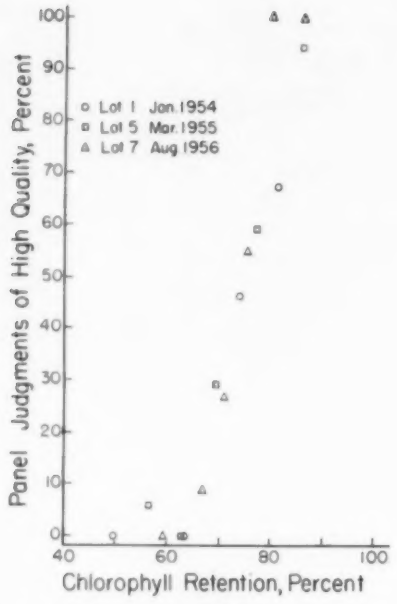

Figure 4. Relationship of chlorophyll retention to high quality judgments (score 1) by industry panels.

to provide an upper standard of quality in the judgment of each lot. Thus, a different standard existed for each lot. The difference in these controls can be seen in the measured chlorophyll retention data which ranged from 72 to 93% in the lots evaluated. It might be expected that lots similar at the start of storage tests would provide data that are comparable (as Lots 1, 5, and 7). However, Lots 6 and 8, which are similar (C_1 = 73.8 and 72.7), were not strictly comparable.

A somewhat more consistent relationship among all 6 lots is seen in Figure 5 on which are plotted the percentage of

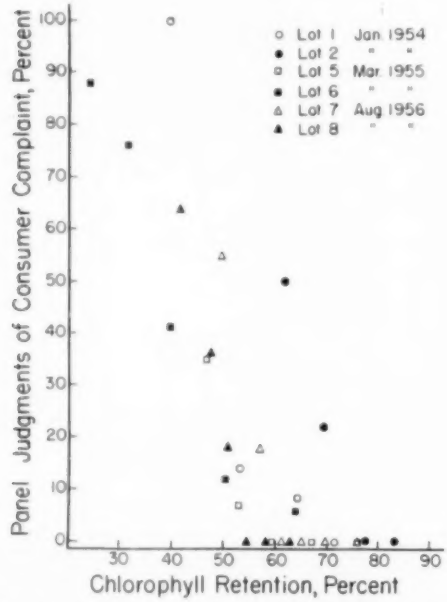
Panel Judgments of Consumer Complaint, Percent
Chlorophyll Retention, Percent
Lot 1 Jan. 1954
Lot 2 " "
Lot 5 Mar. 1955
Lot 6 " "
Lot 7 Aug. 1956
Lot 8 " "

Figure 5. Relationship of chlorophyll retention to consumer complaint judgments (score 3) by industry panels.

judgments scored "3" by the industry panels, against the percentage of chlorophyll retained. This plot may be interpreted as follows: A lot of frozen beans retaining less than 65% chlorophyll will be judged by some industry people as likely to cause consumer complaint; when between 50 and 60% chlorophyll is retained, a majority of industry people will believe that complaints are likely to follow. Therefore, a conservative estimate of a consumer complaint level could be drawn at 50% chlorophyll retention for green beans.

Effect of cyclic fluctuating temperatures. Samples of frozen beans from several lots were subjected to conditions of cyclic fluctuations of storage temperature. In these studies air temperatures were controlled to follow a sine wave pattern on a 24-hour cycle. Subjective evaluations of color and flavor deterioration indicated that rates of change were similar to those of samples stored at constant temperature at the mean of the two temperature extremes.

Objective measurements indicated that deterioration rates were slightly higher than they would be at the mean temperature. This is in accordance with the theoretical considerations expressed by Schwimmer *et. al. (5)* and elucidated by Guadagni and Nimmo *(3)*. Where the observed data were available, 2 methods were used to calculate the constant storage temperature at which the rate of deterioration would be the same as the rate observed for a fluctuating storage temperature. Observed values of chlorophyll deterioration were used to calculate the regression slope, S, as in Figure 1. S was plotted at the appropriate C_1 level in the relationship shown in Figure 3 and an equivalent constant storage temperature ascertained by interpolation between the lines of temperature. For 6 lots of frozen beans, these values are listed in columns "a" of Table 8.

Another value for the constant temperature calculated according to the equations given by Schwimmer *et al. (5)* for each storage study with a fluctuating temperature is shown as columns "b" in Table 8. These were calculated using Q_A values (which express the effect of reaction rate variation over the temperature range) based on observed chlorophyll deterioration rates for constant and fluctuating temperatures.

Values "a" and "b" in Table 8 are in general agreement. Data on the first four conditions of fluctuating temperature storage (−5 to 5, −10 to 10, 0 to 20, and 15 to 25° F.) can be used to develop a general equation:

$$T_E = T_M + k, \qquad (3)$$

where T_E = constant storage temperature required to produce chlorophyll deterioration equivalent to a cyclic fluctuating temperature;

T_M = mean temperature of fluctuation; and

k = a constant dependent upon the amplitude of the fluctuation and the commodity stored. For green beans, where the amplitude equals 10° F., k = 1.9° F.; and where the amplitude is 20° F., k = 4.6° F.

The influence of change of state at the freezing point of the product is again apparent as shown by the calculated value of k = 2.0 (Equation 3) for the 4 storage studies of the fluctuation between 10 and 30° F. This value is less than would be expected from the relationship drawn from data in the temperature range of −10 to 25° F.

As far as these tests go, fluctuation *per se* had no effect on the rate of deterioration of these samples. However, because the rate of deterioration increases exponentially as the temperature increases in a linear manner, the effective deterioration rate of a cyclically fluctuating temperature is higher than the arithmetic mean of the temperature conditions experienced.

Sequence of time-temperature experiences and simulated transportation and distribution effects. The order of time-temperature conditions was varied to ascertain the effect of sequence of separate experiences on total deterioration. In preliminary studies, varied sequences of temperature were used combining 20 with 0° F., and 10 with 0° F. Whether the high temperature experience came first, last, or was interrupted by the lower temperature experience, the total deterioration was about the same, as evaluated by flavor and color judgments

TABLE 8

Effective constant storage temperatures (° F.) having rates of chlorophyll deterioration equivalent to observed values under cyclic fluctuations

Lot No.	Fluctuating temperatures (° F.)									
	−5 to 5		−10 to 10		0 to 20		15 to 25		10 to 30	
	a	b	a	b	a	b	a	b	a	b
1	....	....	5.8	4.4	....	....	21.7	22.5	21.2	22.7
2	....	....	4.9	2.9	....	....	21.3	23.0	20.3	22.2
3	1.2	....	5.4	4.8	15.7[2]	15.5[2]	22.5	22.4	22.9	23.9
4	1.5	....	6.2	5.1	14.8[2]	13.8[2]	23.0	20.1	22.4	20.1
5	0.1	1.7	....	....	14.4	14.8	....	....	....	....
6	2.5	2.5	....	....	12.5	12.2	....	....	....	....
Mean	1.3	2.1	5.6	4.3	14.4	14.1	22.1	22.0	21.7	22.0

[1] a: Interpolated value by use of Figure 3; and b: Calculated value by the method of Schwimmer, *et al.*(5).
[2] Fluctuation followed a sine wave pattern on a 3-day cycle.

and as measured by losses of chlorophyll and ascorbic acid.

Other studies concerned the deterioration of frozen beans subjected to temperature patterns simulating conditions of commercial transport and distribution through retail outlets. Three sets of samples from each of 2 lots of beans were subjected to the conditions outlined in Figure 6. For the 10° F. maximum temperature study, flavor difference from the control (−20° F.) could not be detected at the end of the storage (RDC 10); but in one of the 2 lots, a color difference was observed. The reduced ascorbic acid and chlorophyll measurements showed a quality change, albeit small.

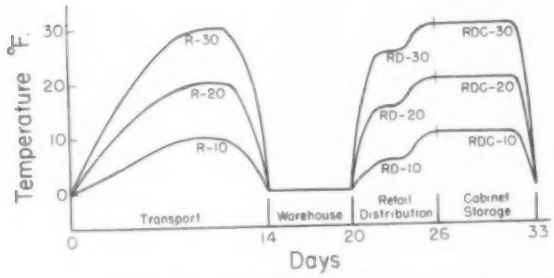

Figure 6. Time-temperature patterns simulating conditions of transportation, warehousing and marketing.

For the 20° F. maximum temperature, flavor and color differences were observed between the control and terminal samples (RDC 20). Color difference but not flavor difference was observed at the end of the simulated transport (R 20). Substantial losses of reduced ascorbic acid and chlorophyll also occurred. These effects were repeated, but in increased amounts of measured deterioration, for the 30° F. maximum temperature conditions. In addition, at this higher temperature, a detectable color difference was observed between samples taken after the transport (R 30) and the distribution phase (RD 30) of the storage pattern. The measured quality factors showed approximately 50% greater deterioration for the 30° F. series than for the 20° F. series at equivalent points.

The RDC 20 pattern, Figure 6, was also used to study the effect of sequences of the various parts on total deterioration. In these sequences the warehouse time at 0° F. (W) was increased from a few days to 8 months, and preceded a transport at 20° F. (R 20) and followed a transport at 18° F. (R 18).* The last 13 days simulating retail distribution and cabinet storage (DC) were the same as in RDC 20 Figure 6. Six replicate determinations were used to establish the amount of chlorophyll retention for W, R 18, R 20, DC, and combinations of these experiences shown as a, b, c, and d in Figure 7. Average percentage chlorophyll retention is also given for the start and termination of each part of each pattern for Lots 7 and 8.

Chlorophyll retention values for whole patterns are compared with sums of the parts of patterns in Table 9. The total deterioration does not vary with sequence of the parts as seen in the comparison of examples i and iii. The small difference between patterns a and b was accounted for by calculating differences in deterioration with slopes (obtained by use of Equation 2) for temperatures 2° F. below the high portion of the R 20 curve, as observed for 6–9 days. The change in ordinary percentage chlorophyll retention for a given part of the pattern is less when the part occurs later in the pattern as seen in the comparison of examples x and xi. The former was preceded by an 8-month storage at 0° F. If arithmetical differences in percentage chlorophyll for the separate parts are added together, as in example v the calculated change is greater (less retention) than for the observed values. When samples for each part of a pattern are stored separately to

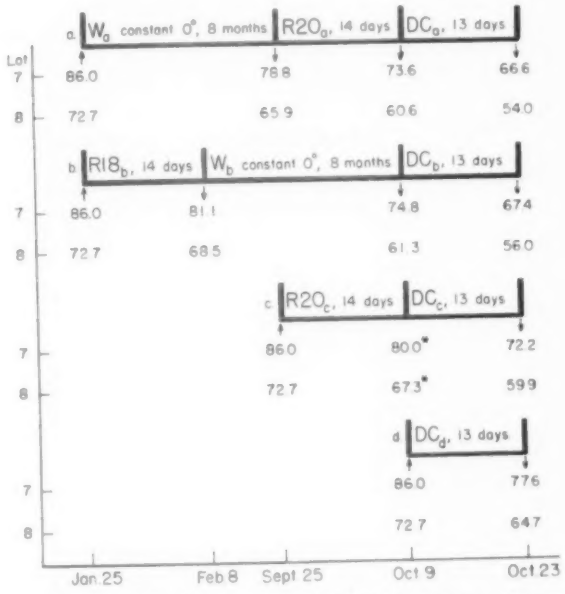

Figure 7. Effect of sequence of simulated patterns of commercial transportation, warehousing, and marketing on chlorophyll retention.

W refers to warehouse, R to transport, and DC to retail distribution and cabinet storage; *a*, *b*, *c*, and *d* refer to the sequence patterns and respective subscripts. Arrows pointing up indicate when samples were placed in and those pointing down indicate when samples were taken out of the sequence. The numbers under the arrows are the percentages of chlorophyll retention. The asterisks in pattern *c* indicate calculated values of percentage chlorophyll retention, based on the log change in percentage chlorophyll retention as observed in pattern *d*.

* The 2° F. difference over part of the curve was caused by a variation in adjustment of the temperature controller.

TABLE 9

Effect of varied sequences of storage experiences on chlorophyll retention

Example	Pattern[1]	Chlorophyll retention (%) Lot 7	Lot 8	Change in chlorophyll retention Lot 7	Lot 8
i	W_a $R20_a$ DC_a	Obs[2] 66.6	54.0		
ii	W_a + $R20_c$ DC_c	Log[3] 66.1	54.3		
iii	$R18_b$ W_b DC_b	Obs 67.4	56.0		
iv	$R18_b$ + W_a + DC_d	Log 67.0	55.3		
v	$R18_b$ + W_a + DC_d	%[4] 65.6	53.7		
vi	W_a $R20_a$	Obs 73.6	60.6		
vii	W_a + $R20_c$	Log 73.3	61.0		
viii	$R18_b$ W_b	Obs 74.8	61.3		
ix	$R18_b$ + W_a	Log 74.3	62.1		
x	$R20_a$ DC_a			Obs 12.2	11.9
xi	$R20_c$ DC_c			Obs 13.8	12.8

[1] Symbols and subscript letters refer to sequence patterns or parts of sequence patterns in Figure 7.

[2] Obs: Observed mean value at end of pattern.

[3] Log: Summation of parts of patterns based on rate of chlorophyll deterioration in each part.

[4] %: Summation of arithmetic differences in percentage chlorophyll.

determine the change in chlorophyll retention from C_1 it is convenient to calculate the sum of the changes in log values for all the separate parts and subtract the summation of log values from log C_1 to obtain the chlorophyll retention at the end of the whole pattern. This is true since the log function of chlorophyll retention and storage time is linear. Chlorophyll retention values calculated by this procedure as shown for examples ii, iv, vii, and ix agree closely with the respective observed values in examples i, iii, vi, and vii as measured at the end of complete patterns.

DISCUSSION AND CONCLUSIONS

Frozen green beans from a broad sampling of commercial operations were tested over a wide range of constant and fluctuating temperatures. Their deterioration followed a well defined course that is described by changes in color and flavor, loss of reduced ascorbic acid, and conversion of chlorophyll to pheophytin.

The number of days of storage at a particular temperature required to cause a detectable flavor or color difference from a control sample of the same lot has been used to provide information on the rates of flavor and color deteriorations. The data revealed the usual exponential effect of storage temperature on deterioration rate. The rate approximately doubled with each 5° F. increase in temperature in the range of 0 to 25° F. Objective criteria of product quality indicated a similar effect of storage temperature on rate of deterioration. That is to say, deterioration rate, as measured by chlorophyll conversion, loss of reduced ascorbic acid, and change in Hunter Color and Color Difference Meter "a" value also about doubled with each 5° F. increase in storage temperature.

Thus low temperature is an important factor in the preservation of quality of frozen beans. Deterioration was negligible at −20° F.; and at 0° F. the products which were initially of high quality maintained good quality for about a year. As the temperature is increased above 0° F., storage life becomes more and more limited.

When the temperature was varied in patterns, deterioration was found to be a summation of time-temperature experiences by all of the criteria of quality used in this investigation. Order of such experiences was of negligible importance. Cyclic fluctuations of temperature caused deterioration that could be expressed completely as a summation of constant temperature increments. No case of reversal of deterioration was found. Once damage occurred, quality was never regained, even though good practices were applied thereafter.

Objective measurements related to quality of product were developed that enable one to define rate and degree of deterioration with reasonable precision and thus provide a useful description of deterioration. The measurement of reduced ascorbic acid, percentage conversion of chlorophyll to pheophytin, and HCM "a" values had an error about half that of the subjective evaluations for color and flavor when comparisons included the variations that existed between lots. The measurement of chlorophyll was found to have a higher precision of individual values and a closer relationship to product quality than the other objective measurements. It made possible an identification of lot-to-lot variation and provided a description of product deterioration that was reduced to an empirical equation of adequate reliability. This depended upon a correlation of the rate of conversion of chlorophyll to pheophytin with the initial chlorophyll level. No substantial variation among the 19 lots was directly attributed to variety, growing area, harvest year, or type of cut.

Green beans blanched at a high temperature for a short time retained a higher percentage of chlorophyll through processing than those blanched at a lower temperature for a longer time to an equivalent degree of peroxidase inactivation. A high retention of chlorophyll coincided with a low rate of deterioration. However, limitations of the experiment preclude the development of a mathematical relationship between deterioration rate and conditions of blanching.

The foregoing suggests means for minimizing deterioration rate of this product by use of high-temperature, short-time blanching conditions. This concept is developed more fully in research reported by Dietrich *et al. (2)*.

A general improvement and increased uniformity of industry practice regarding blanching of green beans could lead to the adoption of the measurement of the percentage retention of chlorophyll as a useful index of quality for the frozen product. At present, it is a valuable tool in the investigation of green bean quality and factors that affect quality. However, the variation in industry practice results in a wide range of initial chlorophyll retention (99 to 66% in 19 commercial lots). Therefore, the chlorophyll retention in a sample of frozen beans should not be used as a general indication of past storage history or anticipated tolerance to future treatment.

For example, if a sample of green beans were to be taken from trade channels and found to have retained 75% of its chlorophyll, then by use of Equation 2

and the experience of this investigation the following extremes of possibility can be calculated:

A. The sample was processed so as to retain 95% of its chlorophyll, has undergone the equivalent of 200 days at 10° F., and is expected to withstand 190 more days at 10° F. before the chlorophyll level is reduced to 60%.

B. The sample was processed to have retained 75% of its chlorophyll, has not undergone storage deterioration, but is expected to withstand only 90 days at 10° F. before the chlorophyll is reduced to 60%.

It is perhaps to be expected that, with improving industry practice, no lot of frozen beans will be produced with less than 85% chlorophyll retention (a level that seems feasible within present equipment limitations). Then the above case can be stated:

C. The sample has had an experience at least equivalent to 70 days at 10° F., and it will withstand at least 120 days more at 10° F. before the chlorophyll level deteriorates to 60%.

Thus, the measurement may become more generally useful as a quality index. In the meantime, it appears feasible for a packer or buyer who is sufficiently aware of the processing conditions used, and condition of his pack of frozen beans at the time of process, to use the chlorophyll measurement to determine the approximate history of a sample of his brand taken at any point in the channels of trade.

Acknowledgments

The authors wish to thank the Refrigeration Research Foundation and its Director, Dr. H. C. Diehl, for providing a substantial portion of the experimental materials used in this investigation; a number of freezing plants, where commercial samples were procured, for their cooperation and assistance; Dr. H. K. Burr for his assistance with some of the mathematical details; Mrs. N. F. Bracelin for illustrative figures; and a group of analysts and laboratory aides, too numerous to mention, whose devotion to duty was as great as any of the authors and who played an essential role in obtaining the experimental data.

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Notes and Letters

Edible Protective Coatings for Extending the Shelf Life of Poultry*

IN THE SELF-SERVICE STYLE of handling meats, maintaining the freshness of the product is of prime importance. Tight-fitting, moisture-proof packaging with low oxygen permeability reduces the rate of decline in the quality of red meats and poultry by reducing moisture loss, microbial development, and rancidity as shown by Margolf *et al. (8)*, Clauss *et al. (3)*, Klose and Lineweaver *(7)*, and Wells *et al. (14)*. However, in packaging poultry the elimination of all air spaces is next to impossible due to the irregular shape of the carcass.

Various coating materials are being used on frozen fish as shown by Whiteleather *(16)* and Jetson *(6)*. Certain coatings have been employed experimentally on red meats as reported by McAllister *(9)* and Westover *(15)* but there has been relatively little work done on spray or dip coatings for eviscerated and cut-up poultry. McNally *(10)* reported that mineral oil or wax was a better coating than corn oil or lard in preventitng weight loss in poultry. More recently, Dawson *(1)* has made some preliminary studies with eviscerated poultry using a resin coating similar to that reported by Westover.

A report by Pearce and Lavers *(11)* on the use of carrageenin (a gelatinous polysaccharide extracted from Irish moss) suggested this study. In 1949, Pearce and Lavers found that dipping eviscerated poultry in a melted solution of carrageenin gel containing 6% sodium chloride prior to freezing would delay the development of off odors in the defrosted carcasses.

In recent years, there have been many reports on various broad spectrum antibiotics as preservatives for fresh fish and poultry. Their value in prolonging the shelf-life of such products is well substantiated in the literature. With the acceptance of the two tetracyclines, aureomycin and terramycin, as preservatives for fish and poultry, it was thought that such nontoxic edible materials as carrageenin and agar might prove of value as a means of increasing the shelf life of fresh poultry when used in conjunction with antibiotics.

MATERIALS AND METHODS

Poultry samples. Unfrozen chicken necks and backs were purchased from a local poultry retailer, washed, and cut into lengths approximately 2½ in. long.

Coating materials. The coating materials tested were marine plant polysaccharides agar and carrageenin gel. Eight hundred ml. quantities of a 3% agar solution with 1% glycerol as a plasticizer and a 4% solution of carrageenin gel were prepared by steaming in an autoclave until the coating materials were melted and in solution. Once melted, the coatings were cooled to, and maintained at 148° F. until used.

Poultry samples were selected at random and immersed in the prepared coatings for 10 seconds; removed; and then redipped for 2 seconds. Any excess coating material which had not solidified was then allowed to drain from the sample before being placed in a sterile one-pint jar and covered. Duplicate samples were wrapped in aluminum foil after coating and placed in one-pint jars to determine the value of the coatings when used with a conventional wrapping material.

Antibiotics. The antibiotics employed were the water soluble salts of chlortetracycline (Acronize P.D.), oxytetracycline (Biostat P.A.), neomycin, and polymyxin B. Two antifungals, mycostatin and sorbistat, were also employed.

The antibiotics were applied to the poultry samples by (a) immersing the samples for one hour in a sterile saline antibiotic solution at 35° F. prior to coating; (b) their direct addition to the prepared and cooled coating materials; and (c) the combination of both of the above. The concentration of the antibiotics used was set at 15 and 20 p.p.m. on a weight basis.

Storage temperatures. Three storage temperatures were employed, 75° F., 55° F., and 35° F. At given intervals—8 hours for 75° F., 12 hours for 55° F., and 24 hours for 35° F.—samples were withdrawn from storage and examined for general appearance, off odors and bacteriologically using the rinse technique *(2)*. The sample was placed in a sterile jar of known weight, reweighed and sterile water added to give a 1:10 dilution on the neck weight basis. The jar was then tightly capped and placed on a Eberbach Shaker for 10 minutes. Appropriate dilutions of the rinse water were made and plated, using nutrient agar. All plates were incubated at 68° F. (20° C.) and read after 96 hours.

RESULTS AND DISCUSSION

The coating materials presented no special problems. Both were easily prepared and equal in ease of application. Coatings did not seriously alter the appearance of the samples and contributed significantly to the prevention of discoloration while the samples were in storage.

At the two higher storage temperatures, 75° F. and 55° F., the coatings proved to be of little value in retarding microbial spoilage. Development of off odors with accompanying bacterial counts of approximately 10^7 per gram occurred in the uncoated controls and coated samples at about the same time. However, at the lower temperature of 35° F., which is more nearly that in properly operated poultry display cases, there was a noticeable increase in the storage time for coated samples wrapped in aluminum foil (Table 1).

The most significant increase in the storage life of the poultry samples was obtained when the coatings were employed with one or more of the antibiotics at a storage temperature of 35° F.

The incorporation in the coatings of either of the two tetracyclines tested proved an effective method

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 28, 1958.

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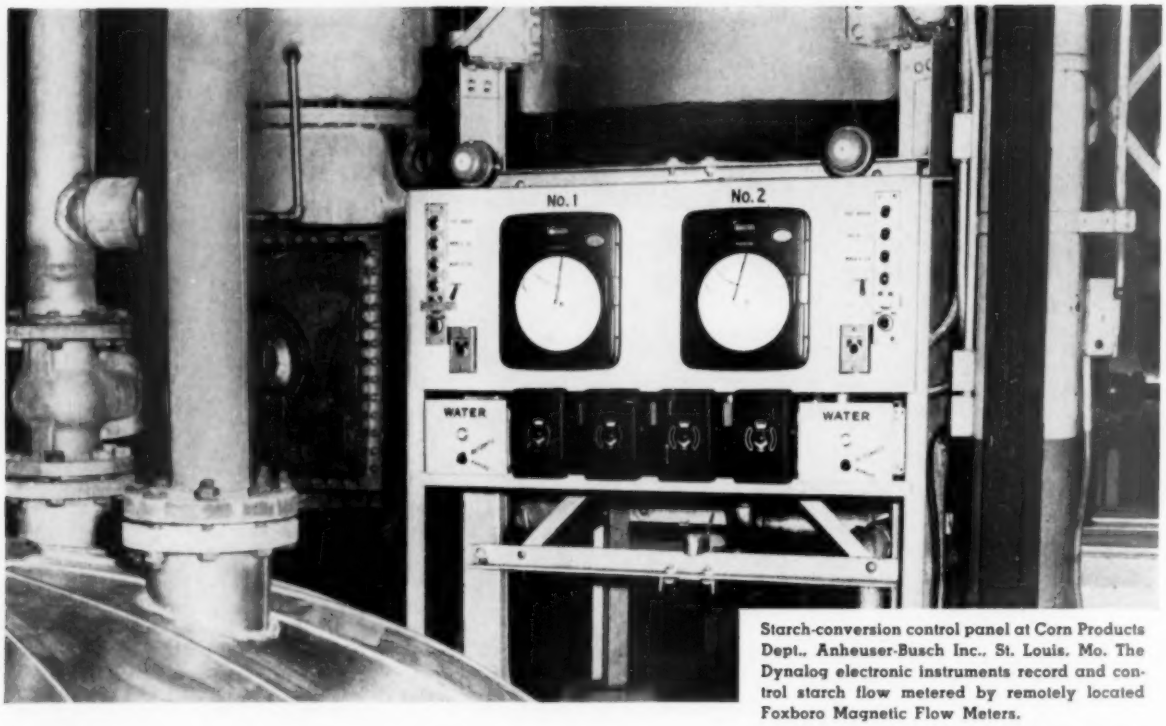

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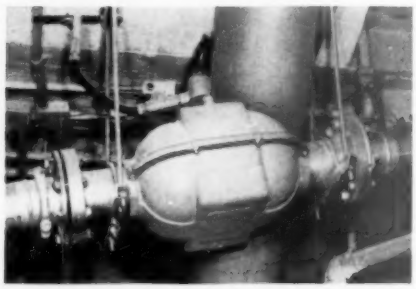
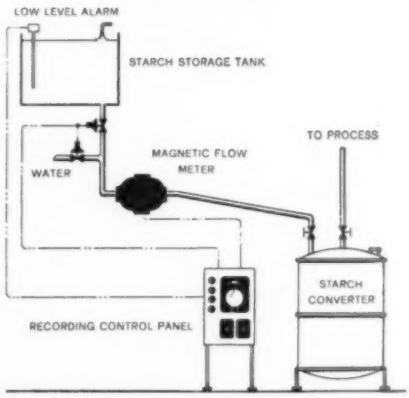


Foxboro Magnetic Flow Meter (above) is one of two installed by Anheuser-Busch to replace batch measuring tank system. Meters provide measurement of starch slurry with better than ±½% accuracy. Diagram for one of the systems is shown below.



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MAGNETIC FLOW METERS

146B

TABLE 1

Effect of coatings in conjunction with aureomycin (CTC) on wrapped samples

Treatment	Log of viable organisms per gram of sample Days stored at 35° F.																		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A1	4.3	....	4.2	4.7	5.0	6.0	7.2	8.4	....	9.3	....	....	9.4	....	....	9.7	....	....	9.8
A2	4.3	3.7	4.2	4.5	4.7	5.2	6.6	7.8	....	9.3	....	....	9.4	....	....	9.5	....	....	9.7
A3	4.3	3.6	4.1	4.3	4.7	5.2	6.6	7.8	....	9.1	....	....	9.2	....	....	9.6	....	....	9.6
B1	4.4	4.5	4.0	4.2	4.4	....	5.5	....	6.8	7.5	7.9	8.4	8.9	8.9	9.3	....	10.2	....	....
B2	4.4	3.9	3.9	....	4.3	....	5.2	....	6.6	7.1	7.7	7.9	8.7	8.4	8.4	....	9.2	....	....
B3	4.4	3.8	4.0	....	4.3	....	5.2	....	6.6	7.2	7.8	7.9	8.5	8.5	9.3	....	9.4	....	....
C2	4.4	....	4.0	4.2	....	4.9	....	5.7	....	7.1	....	7.9	8.0	8.1	8.2	....	9.8	....	9.6
C3	4.4	4.0	4.2	4.1	....	4.9	....	5.7	....	7.0	....	7.9	8.0	8.1	8.2	....	9.4	....	9.6
D2	4.4	3.8	4.0	....	4.5	....	5.1	....	5.8	6.7	6.9	7.0	7.9	8.0	8.0	....	....	9.2	....
D3	4.4	....	4.0	....	4.6	....	5.0	....	5.8	6.7	7.0	7.1	8.0	8.0	8.5	....	....	10.2	....

Key

A1—Control, no coating or antibiotic
A2—Agar coated samples
A3—Carrageenin coated samples

B1—1 hr. dip CTC, no coating
B2—1 hr. dip CTC, agar coated
B3—1 hr. dip CTC, carrageenin coated

C2—CTC incorporated into agar coat
C3—CTC incorporated into carrageenin coat

D2—1 hr. dip CTC, plus CTC incorporated into agar coat
D3—1 hr. dip CTC, plus CTC incorporated into carrageenin coat

* Double line indicates time at which spoiled odor became evident.

for the application of such antibiotics. Use of the coatings containing the antibiotics were more effective in retarding spoilage than the one hour dip in the antibiotic-saline solution. Results obtained for the two coating materials and the two accepted tetracyclines, chlortetracycline (CTC) and oxytetracycline (OTC) were nearly identical. The findings are in general agreement with results published by Ayres *et al. (1)* and Vaughn *(12)*.

The longest keeping times for treated samples were obtained from a combination of one or more of the tested antibiotics and antifungals.

Exlund, Spencer and associates *(5)* and Wells *et al. (13)* reported that chlortetracycline used as a preservative in processed poultry resulted in yeast growth over the product and that yeast appeared to be responsible for a major portion of the spoilage that occurred during storage. Yacowitz, Pansy, et *al. (17)* obtained control of yeasts by the addition of 10 p.p.m. mycostatin to the conventional chlortetracycline dip. Addition of 15 p.p.m. chlortetracycline or oxytetracycline and 10 p.p.m. mycostatin to the coating materials resulted in a significant increase in storage life over the use of chlortetracycline or oxytetracycline alone (Table 2).

These findings give support to the statement of Ayres and Walker *(1)*: "The probability exists that a combination of antibiotics could be selected in such a manner that their complementary action will markedly retard the development of bacteria and fungi."

SUMMARY

Two edible coating materials, agar and carrageenin gel, while not substantially altering the appearance of poultry samples were of little value in retarding microbial spoilage at storage temperatures of 75° F. and 55° F. At 35° F. there was a slight increase in

TABLE 2

Effect of coatings in conjunction with aureomycin (CTC) and mycostatin on wrapped samples

Treatment	Log of viable organisms per gram of sample Days stored at 35° F.																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A1	4.2	3.2	4.1	5.4	6.1	6.6	7.7	7.9	8.1	....	9.3	....	....	9.5	....	9.6	....	....	9.8	....
A2	4.2	4.2	....	4.6	....	6.3	....	7.8	....	9.4	....	9.6	....	9.5	....	9.6	....	9.4	....	9.8
A3	4.2	3.9	....	4.2	....	5.3	....	5.5	....	5.9	....	6.9	....	8.1	....	8.7	....	9.3	....	9.7
A4	4.2	3.6	....	4.0	....	5.2	....	4.5	....	4.7	....	6.3	....	6.0	....	7.5	....	9.1	....	9.7
B2	4.4	4.5	5.1	....	5.4	....	5.7	....	5.8	....	8.8	....	7.6	....	8.4	....	8.5	....	9.2	9.4
B3	4.4	....	4.3	....	4.5	....	5.0	....	5.7	....	5.8	....	7.6	....	7.5	....	8.3	....	9.1	9.5
B4	4.4	....	4.5	....	4.5	....	5.0	....	5.5	....	5.9	....	7.1	....	7.9	....	8.1	....	9.2	9.7

Key

A1—Control, no coating or antibiotics
A2—Agar coated samples
A3—Agar coat containing 15 p.p.m. CTC
A4—Agar coat containing 15 p.p.m. CTC and 10 p.p.m. Mycostatin

B2—Carrageenin coated samples
B3—Carrageenin coat containing 15 p.p.m. CTC
B4—Carrageenin coat containing 15 p.p.m. CTC and 10 p.p.m. Mycostatin

* Double line indicates time at which spoiled odor became evident.

keeping time of coated and wrapped samples compared to the non-coated controls. The coatings proved most effective when used with a wrapper in conjunction with one of the tetracyclines or a combination of antibiotics at a storage temperature of 35° F.

Use of agar or carrageenin coating as a vehicle for the application of water soluble antibiotics proved successful. The results indicate that such a technique may be superior to the present antibiotic dip or wash now employed by some processors to increase the shelf-life of poultry.

In a comparison of chlortetracycline and oxytetracycline it was found that the two antibiotics gave comparable results when incorporated into the coatings.

The two tetracyclines, oxytetracycline and chlortetracycline, proved most effective when incorporated in the coating materials in combination with other antibiotics or antifungals than when either was employed alone.

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H. H. Weiser
The Ohio State University,
Columbus, Ohio

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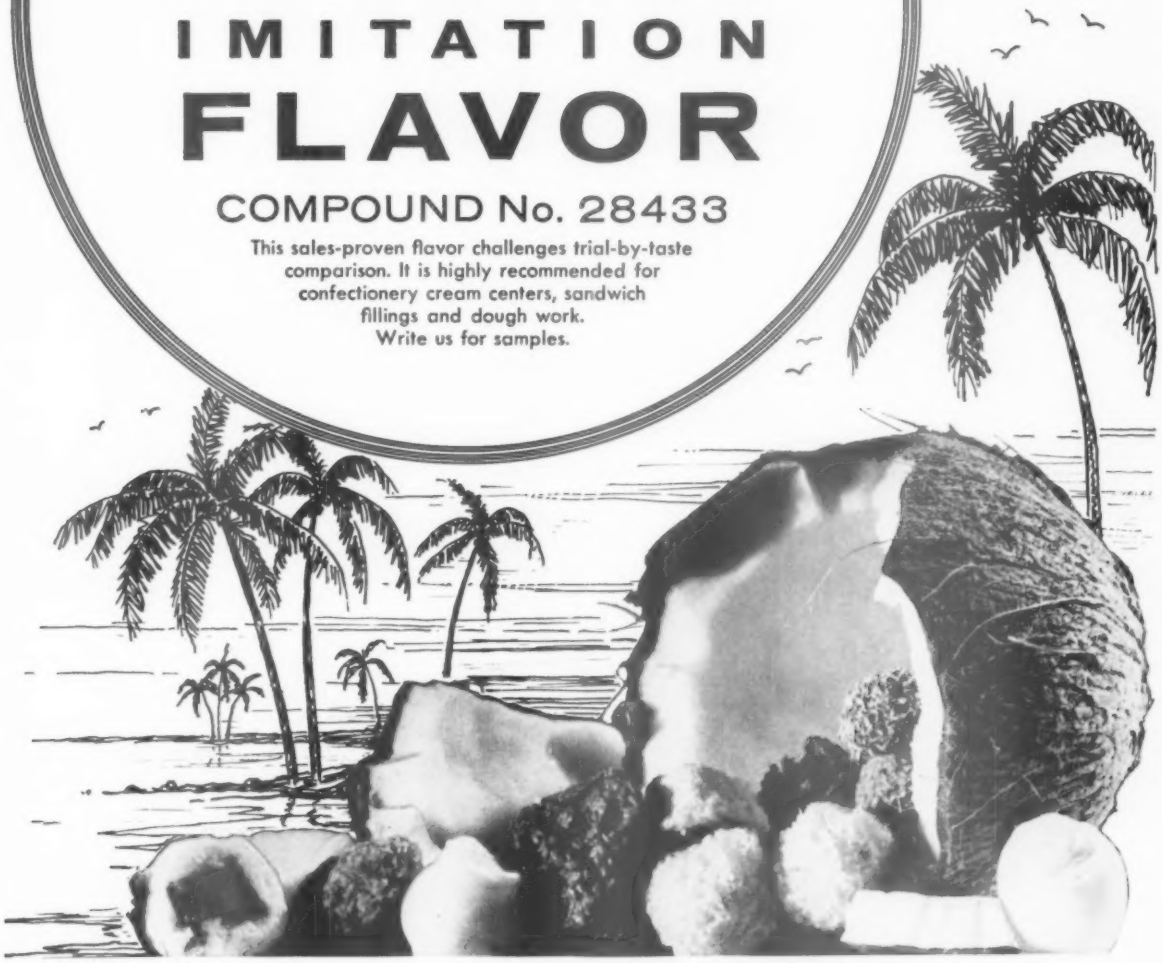

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(Continued from page 18 preceding technical section)
Polyoxyethylene (8) Stearate for Use in Foods." Printed copies may be obtained shortly by writing to Dr. Paul E. Johnson, Executive Secretary, Food Protection Committee, 2101 Constitution Avenue, Washington.

Joint FAO/WHO Expert Committee on Food Additives. The third session of the Joint FAO/WHO Expert Committee on Food Additives was held in Rome on December 1–8, 1958, under the chairmanship of Dr. A. C. Frazer, University of Birmingham, England. Those attending from the United States included Dr. H. C. Spencer of Dow, Dr. W. M. MacNaughton of Tennessee Eastman, Dr. B. L. Oser of Food and Drug Research Laboratories, and Dr. J. F. Mahoney of Merck. The purpose of the meeting was to discuss the establishment of specifications for food additives with particular reference to antimicrobial preservatives and antioxidants. The committee's report is to be published by FAO and by WHO later this year (1959).

HEW Department Meetings with National Organizations. Dr. Arthur S. Flemming, recently appointed Secretary of the Department of Health, Education, and Welfare, has concluded a series of 12 meetings at which representatives of about 700 national organizations were asked to discuss the Department's program and activities. Three of the meetings were devoted specifically to the Food and Drug Administration. Dr. J. F. Mahoney, as chairman of the Food Additives Committee, represented the Institute of Food Technologists at the final meeting held on December 18.

Dr. Mahoney, addressing the group, stated in part:

The Institute of Food Technologists and the FDA certainly are united in their desire to insure that the American public receives a varied, wholesome, abundant, and economical food supply. It is significant that so many of the food scientists of the FDA are also members of IFT. In considering specific ways in which our common goals can be implemented, I should like to mention these points:

1. The enactment of the Food Additives Amendment of 1958 has raised many questions of interpretation and administration. The first set of proposed definitions and procedural and interpretative regulations were issued only a few days ago. We believe it is important that our food technologists as well as our lawyers understand these definitions and regulations, and we urge that FDA consider the most effective means by which this can be accomplished. We believe this will be of particular value to small organizations where compliance with the provisions of the Federal Food Drug and Cosmetic Act is often the responsibility of the food technologist.

2. We must view with concern the number of articles which have appeared and are continuing to appear in the press to the effect that the American public is being harmed by the use of food additives. The fact that such a conclusion is simply not true does not lessen the fact that these articles tend to lower the confidence of the public in the wholesomeness of our food supply.

This situation is of concern to many organizations, including the Institute of Food Technologists, and considerable thought is being given to ways in which the important and essential role of food additives in safeguarding and improving our foods can be brought to the public's attention. I am sure the Food and Drug Administration participation in this effort would be welcomed.

IFT NEWS

FUTURE MEETINGS FOR FOOD TECHNOLOGISTS

1959	
February 13-15	30th Fact Finding Conference, Sponsored by the Institute of American Poultry Industries, Municipal Auditorium, Kansas City, Missouri
February 21-24	Convention of the National Canners Association, Conrad Hilton Hotel, Chicago, Illinois
February 26-27	7th Annual National Dairy Engineering Conference, Kellogg Center, Michigan State University, East Lansing, Michigan
March 1-5	Convention of the National Association of Frozen Food Packers, Conrad Hilton Hotel, Chicago, Illinois
March 4-6	Southeastern Conference on Better Foods, The Georgia Center for Continuing Education, University of Georgia, Athens, Georgia
March 31-April 2	Annual Meeting of the Research and Development Associates, Food and Container Institute, Inc., Statler Hotel, Washington, D. C.
April 5-10	135th National Meeting American Chemical Society, Boston, Massachusetts
April 20-22	American Oil Chemists Society Spring Meeting, Roosevelt Hotel, New Orleans, Louisiana
April 28-May 1	Annual Convention of the Institute of Food Technologists, Australia, Mayer Chalet, Warburton, Victoria
May 17–21	**Nineteenth Annual Meeting of the Institute of Food Technologists, Bellevue-Stratford Hotel, Philadelphia, Pennsylvania**
June 7-11	76th Annual Convention of the National Confectioners Association, Conrad Hilton Hotel, Chicago
June 9-13	Second Inter-American Food Congress, Carillon Hotel, Miami Beach, Florida
June 10-12	Second International Symposium on Gas Chromatography, Kellogg Center, East Lansing, Michigan
June 11-12	Canadian Institute of Food Technology, 2nd National Conference, Royal Hotel, Toronto

1960	
May 15-19	**Twentieth Annual Meeting of the Institute of Food Technologists, Fairmont Hotel and Masonic Temple, San Francisco, California California**
1961	
May 7-11	**Twenty-first Annual Meeting of the Institute of Food Technologists, Hotel Statler, New York, New York**
1962	
June 17-20	**Twenty-second Annual Meeting of the Institute of Food Technologists, Amercana Hotel, Bal Harbor, Miami Beach, Florida**

An open invitation is extended to readers of FOOD TECHNOLOGY to send in to the Editorial Office, 11606 South Bell Avenue, Chicago 43, Illinois notices of annual or national meetings of interest to food technologists.

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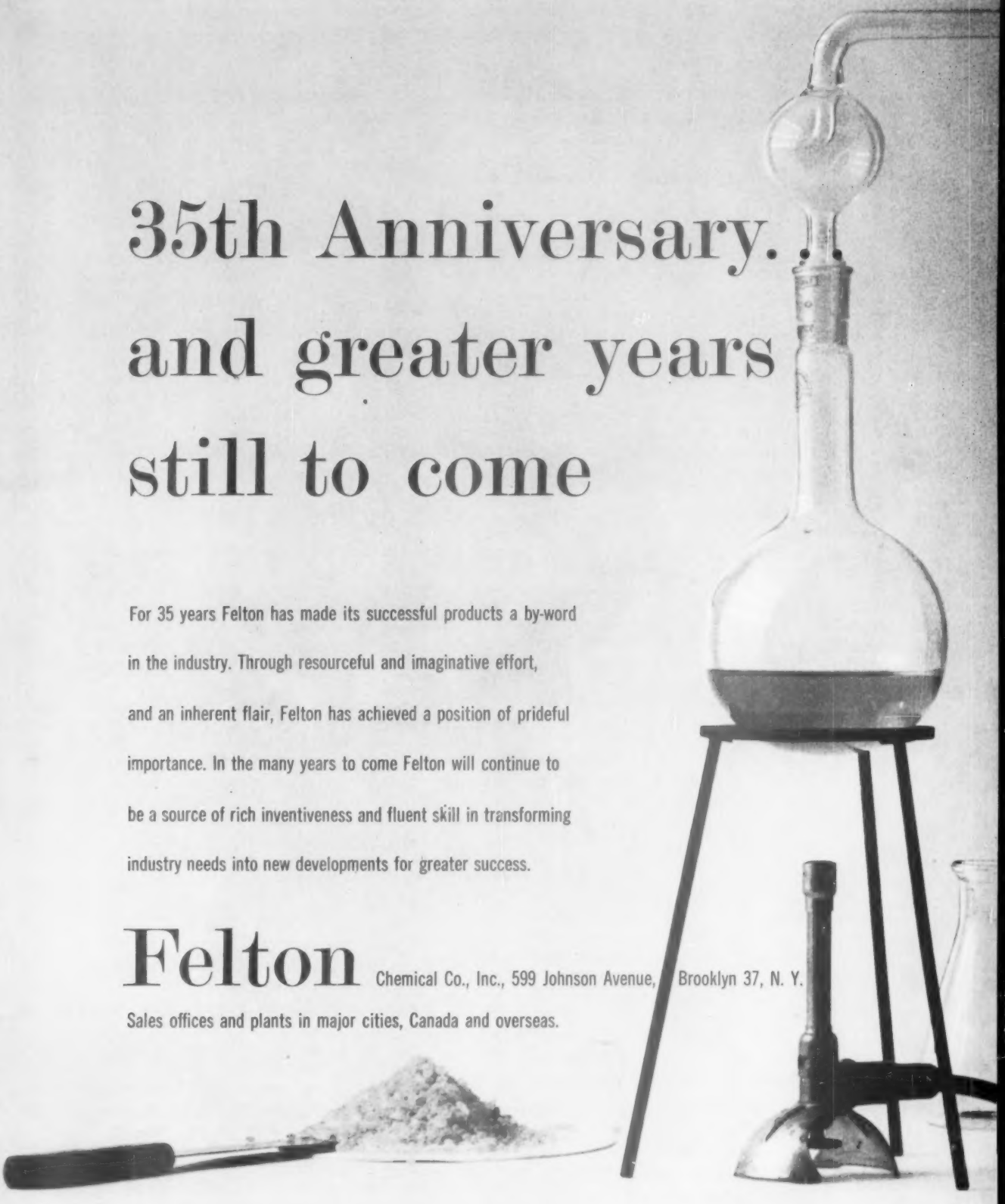

New York Sanitation Methods School

In cooperation with the U.S. Food and Drug Administration, the American Association of Cereal Chemists, New York Section, will hold a Sanitation Methods School in New York City on February 16 to 21, 1959 at the New York City Community College of Applied Arts and Sciences, 300 Pearl St., Brooklyn 1.

The project is the direct result of the work of the Sanitation Methods Committee of the AACC, and will train personnel in the cereal industry in latest sanitation procedures. This will include methods for determining contaminants in cereal grains and their products through X-ray techniques, and the identification of insect fragments and rodent hairs. A nominal registration fee of $6.50 will cover the cost of supplies. Instructors will be furnished by the U.S. Food and Drug Administration. Application forms, and further information regarding the course may be obtained by contacting Mr. Andrew J. Allgauer, whose address is: Ward Baking Company, 367 Southern Boulevard, Bronx 54, N.Y.

Food Technology Short Course

How are food product quality and identity protected during the successive stages from the raw material to the consumer? This will be the theme of the seventh annual Food Technology Short Course to be held in Columbia, Missouri on March 13 and 14. As in past years, this two day technical meeting will be sponsored jointly by the St. Louis Section, the University of Missouri and the Kansas City Section.

The theme to be developed is product quality maintenance, not only in the finished stages but from every aspect of the development from the farm to the table. Thus agricultural, purchasing, manufacturing, stability and packaging problems will be successively taken up.

There will be two half day sessions on Friday of the meeting and a third on Saturday morning. A new feature this year on Friday afternoon, replacing the previous tours of the Missouri campus, will be a time of informal table discussion. The main meeting will divide into small discussion groups which will consider, under selected leaders, a number of topics related to the principal subject of the meeting.

A rough outline for the program has now been established as follows:

"Food Product Uniformity—from the Producer to the Consumer"

I. Raw Materials
  Unprocessed
    Agriculture
    Purchasing
  Processed
    Perishable
    Non-perishable

II. Processing
  Continuous
  Batch
  Plant Personnel

III. From the Factor to the Consumer. Protecting the Finished Product from Plant to Table
  Fresh, frozen, and canned products
  Laboratory control
  Statistical control

Our national chairman, Dr. Aksel Olsen has agreed to be the speaker at the dinner on Friday night and acceptances have been received from outstanding speakers for other key spots on the program.

REGIONAL NEWS

WISCONSIN

The fall activities of the Wisconsin Section began in Racine on September 26. A tour of the Wright designed "Research Tower" at the Johnson Wax Company preceded dinner and an excellent discussion of "New Developments in Corn Sirup Technology and Their Applications in Foods Processing" by Mr. J. W. Evans, American Maize Products Company, Roby, Indiana.

Meeting next at Milwaukee on October 24, the Section enjoyed a tour of the Continental Can Company facilities there. Following a buffet dinner at the Schlitz Country Club, Dr. Lloyd Hall of the Griffith Laboratories, Inc., Chicago, presented an interesting review of spices and advances in spice technology.

On November 21, the Section held its Annual Meeting at the Cuba Club in Madison. Officers elected for the forthcoming year are as follows:

Chairman elect—Oswald Freund, Red Star Yeast and Products Co., Milwaukee.

Secretary-Treasurer—Andrew C. Rice, University of Wisconsin.

Member at Large—John J. Birdsall, Wisconsin Alumni Research Foundation.

Section Councilor—Ara O. Call, Western Condensing Co., Appleton.

Dr. K. G. Weckel, University of Wisconsin will be the Chairman for the 1959 activities of the Section.

Following the annual business meeting, the Section was addressed by Mr. Norman O. Sorenson, Country Gardens, Inc., Milwaukee and Mr. Hy Pitt, Oscar Mayer and Co., Madison. Mr. Sorenson, President of the National Canners Association, spoke briefly on the importance of technical advances, group discussion and dissemination of information to the food industries through IFT. Mr. Pitt then gave a stimulating discussion of the basic role of statistics in food technology.

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MOHAWK VALLEY

The Mohawk Valley Regional Section of Institute of Food Technologists met Thursday evening, December 18, at the Canajoharie Hotel. The meeting began with a social hour that preceded a buffet dinner. William Nye, Jr., Chairman of the Mohawk Valley Section, called the meeting to order and a brief business session was held.

The election of 1959 officers of this section was announced; the 1959 officers are:

Chairman-elect, Henry C. Strecker, Beech-Nut Life Savers, Inc., Canajoharie, N. Y.

Vice Chairman, John W. Stewart, Chairman of Food Technology Department, State University Agricultural and Technical Institute, Morrisville, N. Y.

Secretary-Treasurer, Miss Dorothy Van Schaick, Beech-Nut Life Savers, Inc., Canajoharie, N. Y.

Corresponding Secretary, H. Charles Nixon, Beech-Nut Life Savers, Inc., Canajoharie, N. Y.

Councilor, Theodore F. Irmiter, Salada-Shirriff-Horsey, Ltd., Little Falls, N. Y.

Following the business meeting came the highlight of the program. Dr. Aksel G. Olsen, President, Institute of Food Technologists, was the principal speaker. Dr. Olsen spoke on current status of the Institute, outlining its functions and activities. Succeeding this, Dr. Olsen presented a talk "Industrial Research and Research Planning." Slides were used to illustrate Dr. Olsen's talk.

The Mohawk Valley Section was happy to meet, talk with, and listen to Dr. Olsen.

Thursday evening, September 18, the Mohawk Valley Regional Section, Institute of Food Technologists, met at State University of New York Agricultural and Technical Institute, Morrisville, New York. Our hosts were John W. Stewart (center), Chairman of Food Technology Department, State University Agricultural and Technical Institute, with associates Howard Deane (left) and Glen H. Olmstead (right).

Dr. David B. Hand

Highlights of the program were: 1. A guided tour through Shannon Hall, the new food processing laboratory which has modern facilities for processing of foods, including both canning and freezing. 2. Dinner prepared by seniors of home economics department. 3. Excellent presentation by Dr. David B. Hand of Geneva on "Chemical Additives in Foods" in lecture room of Shannon Hall.

Thursday evening, November 20, the Mohawk Valley Regional Section, Institute of Food Technologists, met at the Little Falls Country Club, Little Falls, New York. Junket Brands Food, division of Salada-Shirriff-Horsey, Inc., acted as host for the group, and a buffet luncheon was served. The principal speaker for the evening was Mr. O. C. Holland, director of advertising for Interchemical Corporation, printing ink division. Mr. Holland gave a talk on color in the graphic arts field and how to use color. He used slight-of-hand and "color magic" to explain color and show how it fools the eye. He also gave eye-popping demonstrations with brilliant colors, powerful lights, sparkling lights, and even used magnetism. He is often referred to as the "color magician". His talk was very informal and entertaining, ranging all the way from electronics to psychology. Fifty-four members and guests attended the meeting. —*Kenneth Bracebridge*

INDIANA

The next meeting of the Indiana Section will be March 3. The following is the schedule for this event.

12:30 P.M., E.S.T.—Lunch Turner's Athenaeum, 401 East Michigan Street, Indianapolis

1:30 P.M.—Tour of the Stokely Van Camp Plant, 2002 South East Street, Indianapolis; Mr. Rutledge in charge

5:45 P.M.—Social hour Turners Athenaeum

6:30 P.M.—Dinner. The after dinner address will be given by Mr. Ray B. Wakefield, Director of Research and Quality Control for Gerber Products Company and Chairman Elect of the National I.F.T. Mr. Wakefield's topic will be "Current Problems of the National I.F.T."

The Section's November meeting at Purdue University was designed to introduce students in Food Technology and related subjects to leaders of industry in the Indiana Area. "What I Do as a Food Technologist" was the subject for the following speakers: Mr. Virgil Rupp, Kingan Division, Hygrade Food Products Corporation; Dr. A. C. Shuman, Shuman Laboratories; Mr. Vern Walters, Pest Control Services Inc.; Dr. J. R. Stockton, The Pillsbury Company; Mr. Fred Dellwo, Ball Brothers Company; and Mr. Leslie F. Rutledge, Stokely Van Camp, Incorporated.

This program was a continuation of the Section's "Career Day" efforts. It served to inform the students already enrolled in Food Technology of what industry wants in trained personnel. The students learned from the experts the scope of our industry and the wide variety of challenging job opportunities which await the qualified man. This type of meeting should make the student even more enthusiastic about our profession. Representatives of fourteen companies and two universities were present to support this new endeavor.

Dr. Richard Kohls of the Agricultural Economics Department at Purdue discussed the economics of food processing and packaging at the evening dinner meeting. Dr. Kohls' remarks were well received by the membership.

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BRITISH COLUMBIA

The B.C. Section of the Institute of Food Technologists held its regular meeting on Thursday, November 27, in the Kelly-Douglas Auditorium in Vancouver. Most of the staff of the Fruit and Vegetable Processing Laboratory at Summerland, B.C., travelled over 260 miles across the snowy Coast Mountains to speak to us on their activities.

Mr. F. E. (Ted) Atkinson, who has been in charge of the lab since its inception in 1929, told of their apple cider development work. Also included were some of the highlights of Ted's recent trip to Europe where he studied European cider and juice manufacture. John Bowen spoke on his work on bacterial counts in frozen vegetables and the relationship of this research to quality control in the plant. Next, John Kitson discussed methods being studied for peeling tomatoes for canning. In the course of these studies, an interesting geographical variation in pH was discovered. Further work is planned to establish the cause of this variation. Dr. John Matthews, who holds a National Research Council post doctoral fellowship, is working at the lab on biochemical changes in cider during aging. As his work here is just beginning, he spoke to the group of his work in Switzerland on wine yeast metabolism. Dr. Dugal MacGregor told of his work on concentrated juices and purées and their potential uses. A. W. Moyls reviewed the research work that led up to the commercial development of a B.C. pack of high quality fruit pie fillings. John Ruck discussed his studies on the insoluble solids content of fruits and its uses as a quality criteria for jams and pie fillings. Miss Dorothy Britton spoke on the role of the test kitchen in developing useful recipes for fruit and trying out the products developed by the research group in the pilot plant.

Each speaker's time was strictly limited by a gong in timer George Claydon's hand, but nevertheless they all very ably conveyed to the audience their enthusiasm for their work. The third year class in Home Economics from U.B.C. swelled the gathering to more than 85 persons. After a number of interesting questions, Mr. Granville Boothley of the Canadian Fishing Company thanked the speakers on behalf of the group. Chairman Chuck Bullen adjourned the meeting for refreshments and an hour of informal discussion.

NORTHEAST

Visitors to the Boston area will be interested to learn of the changes in our meeting schedule. A cordial welcome is extended for the second Tuesday in each month at the MIT Faculty Club: cocktails at 5:30; good food for food technologists at 6:30; food for thought at 8:00. Thus, on November 18, over 80 members and guests attended the dinner for Winston Bradshaw of Union Carbide Chemicals Corporation who gave a lively illustrated account of sorbic acid as "the modern food preservative".

Four weeks later, December 16, 130 members and their wives came to hear Dr. Ernest Guenther, Vice President and Technical Director of Fritzsche Brothers, Inc. who has recently returned from a 15,000 mile journey in and about Africa in search of essential oils. Besides being a peerless raconteur, Dr. Guenther has a talent for photography. He gently took the audience by the hand and led them into the whys and wherefores of essential oils, first by his talk, then by an illustrated lecture on the spice islands of the Caribbean, and finally by the abbreviated log of his African trip as recorded in color film amplified by sound and aerosol sprays.

In a small way, the NE section is attempting to spread the gospel of food technology to local science teachers. According to plans, at least one high school teacher will be a guest at each meeting. The head of the science department of Norwood High School was introduced to the group at the most recent meeting.

KANSAS CITY

Our second year as a chartered section has gotten off to a good start. As of this writing, three of the nine meetings scheduled for the 1958-1959 season have been held. These dinner meetings, with the speakers and their subjects were as follows:

September 25. Dr. L. D. Morse, Professor, Family Economics, Kansas State College, "Factors and Problems Related to Consumer Acceptance of Foods"

October 23. Dr. Nelson Allen, Chestnut Run Laboratory, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware, "Packaging with Flexible Films"

November 20. Dr. Bruce H. Morgan, Assistant Manager of Packaging Engineering, Continental Can Company, Inc., Chicago, Illinois, "Biological Phenomena in the Irradiation Sterilization of Foods"

Although recessed in December, we will continue with monthly meetings next year up through June. Most of these will be dinner meetings held on the third Thursday of the month at the Twin Oaks Restaurant, 5050 Oak Street. The 1959 schedule is:

January 15. Dr. Mark L. Morris, Topeka, Kansas, "Nutrition, Medicine and Advances in Food Technology."

February 14. Luncheon at Kansas State College, Manhattan, followed by a tour of the facilities in food technology. Those who wish will stay for the Kansas-Oklahoma State basketball game in the evening.

March 19. Mr. Franc A. Barada, District Sales Manager, Fritzsche Brothers, Inc., St. Louis, Mo. will present Dr. Ernest Guenther's film on "Essential Oil Production in Southeastern Africa"

April 23 and May 21. To be announced.

June 18. Tour of Midwest Research Institute, Kansas City, Mo.

Officers for the 1958-1959 season are: Mr. Robert A. Maxwell, Chairman; Mr. James M. Gorman, Chairman Elect; Mr. O. A. Rose, Counselor; Dr. H. E. Newlin, Secretary; Mr. Gunther Doerfert, Treasurer.

Literature

BOOKS

OUR DAILY BREAD. E. J. Pyler, Siebel Publishing Company, Chicago. 1958, 157 pp.

This text is limited to a discussion of enriched white bread. As Mr. Pyler notes, 80% of all the bread purchased in the United States is of this type. The discussion, which is quite general, is oriented more to inform professional people not connected with the baking industry about the manufacture, ingredients and nutritive value of enriched white bread rather than members of the baking or allied industries. Members of these latter groups would find that this book contains too elementary a coverage of their major product.

The subject is presented under six major topics: (1) a survey of the history of baking and its effect on the growth of civilization; (2) the chemical and physical composition of wheat and flour, including a brief discussion of the milling process; (3) miscellaneous bread ingredients; (4) the technology of bread baking; (5) the composition of bread; (6) the nutritive value of bread. There is also a brief appendix which outlines the Federal Standards of Identity for certain bread products.

The most interesting chapter to this reviewer is the one on the history of baking. This informative and entertaining section begins in 6,000 B.C. and touching on various highlights of the improvements in bread technology and the history of the times, continues until the present, leaving the solution of various problems still facing the industry to the future. The other chapters contain broad and, in many cases, too brief outlines of bread manufacture, composition and nutrition.

The discussion on the composition and nutritive value of bread is brief and in various places inconsistent. There is an overemphasis on results of the McCance-Widdowson studies of the nutritive value of bread, especially since these studies have been a subject of controversy and it appears that their exact value has not been satisfactorily defined.

This book covers its subject in a fairly general and basic manner. As a source of introductory material for college students and professional people not directly concerned with the baking industry, this book may be of use.

CHARLES FELDBERG
Brooklyn, New York

LITERATURE ON FOOD RESEARCH AND TECHNOLOGY*

* Material for this list should be sent to Dr. James G. Hodgson, Chief, Library Branch, Quartermaster Food and Container Institute for the Armed Forces, 1819 W. Pershing Road, Chicago 9, Illinois.

Commodities

All about candy and chocolate. Philip P. Gott, L. F. Van Houten, Rohland A. Isker, Kathryn E. Langwill and L. F. Martin. Nat'l Confectioner's Assoc., Chicago, Ill.

Making and preserving apple cider. James F. Robinson and others. Washington, U. S. Govt. Print. Off., 1958. 16 p. (U. S. Dept. of Agriculture. Farmer's bulletin, 2125.) pap. $0.10. Supersedes FB 1264. From Eastern Utilization and Research Division, in cooperation with the Department of Food Technology, University of Massachusetts, and the National Apple Institute.

Food Engineering and Technology

Processed plant protein foodstuffs. Arnold M. Altschul, ed. New York, Academic Press, 1958. 955 p. $26.00.

Processing of frozen french fried potatoes and other potato products. I. C. Feustel and W. O. Harrington. Washington, 1957. 23 p. (U. S. Dept. of Agriculture. Agricultural research service, ARS-74-8. pap. apply.

Radiation preservation of foods. U. S. Army Quartermaster Corps. Washington, U. S. Army General Staff. Research and Development, 1958. 461 p. (United States army research and development series, no. 1.) Thirty-three chapters by different authors, with full bibliographies, covers all aspects of radiation as applied to the preservation of foods.

Tin coating of cans for certain subsistence items, phase 2, final report, June 19, 1954–January 31, 1956. Chicago, Quartermaster Food and Container Institute, 1958. 17 p. pap. Available from U. S. Dept. of Comm. O.T.S., as PB 131637. $0.50.

Biological Aspects

A guide to the history of bacteriology. Thomas Grainger, jr. New York, Ronald Press, 1958. 221 p. (Chronica Botanica, no. 18.) $4.50.

Food for better performance. R. C. Hutchinson. Melbourne, Australia, Melbourne University Press, 1958. 102 p. 13s6d, Australian. Nutritional needs for both physical and mental activities.

Metabolism of lysids. British Medical Bulletin. 14(3) September 1958. The Medical Dep't, The British Council, 65 Davies Street, London, W 1. Price $3.25. Twelve papers composing a symposium on the major issues currently being discussed with regard to lipsid metabolism including absorption of sterols, etc., etc.

Physiology of fungi. Vincent W. Cochrane. New York, John Wiley, 1958. 537 p. $9.75. Effects of physical and chemical agents on growth is also covered.

Proceedings of the Borden Centennial Symposium on Nutrition. The nutrition "ages of man." New York (17), Borden Company Foundation, 350 Fifth Avenue, 1958. 144 p. pap. apply. Papers by leading nutritionalists presented April 12, 1958 in celebration of the 100th anniversary of the founding of the Borden company.

Chemical Aspects

Biochemistry of the nucleic acids. 3d ed. James N. Davidson. New York, John Wiley, 1958. 256 p. $4.00.

Carbon dioxide in water, in wine, in beer, and in other beverages. F. Justin Miller. Oakland, Calif.

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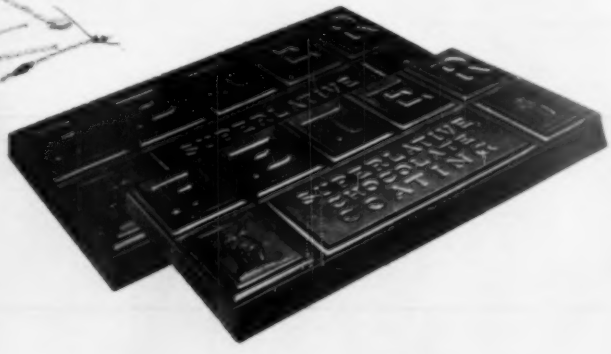

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Chemical kinetics of enzyme action. Keith J. Laidler. London, Oxford University Press, 1958. 428 p. 60 s.

Chemical transformations by microorganisms. Frank H. Stodola. New York, John Wiley, 1958. 143 p. (E. R. Squibb lectures on chemistry of microbial products.) $4.25. Chemical composition, organic type reactions, and synthetic powers of microorganisms.

Introduction to the chemistry of fats and fatty acids. F. D. Gunstone. New York, John Wiley, 1958. 171 p. $6.00.

Symposium on protein structure. International Union of Pure and Applied Chemistry. Paris meeting, 1957. London, Methuen, 1958. 352 p. 45 s.

Vitamins and hormones. Robert S. Harris and others eds. New York, Academic Press, 1958. 449 p. (Advances in research and application, v. 16.)

Economic Aspects

Consumers appraise canned and frozen foods, their packaging and labels in Atlanta, Kansas City, and San Francisco. Daniel B. Levine. Washington, U. S. Govt. Print. Off., 1958. 77 p. (U. S. Dept. of Agric. Agricultural marketing research reports, 270.) pap. $0.45.

Costs of handling Florida oranges shipped in consumer bags and in bulk. G. L. Capel. Gainsville, Fla., 1958. 23 p. (Florida. Agricultural Experiment Station. Agr. econ mimeo. rpt. 58-12.) pap. apply.

Yearbook of food and agricultural statistics, v. 11, 1957. Food and Agriculture Organization. New York, Columbia University Press, 1958. 2 v. Pt. 1, $3.50. Pt. 2, $3.50. Vol. 1 is on production and v. 2 on trade. Several new countries are covered that were not in the previous annual reports.

Miscellaneous

Asymptotic methods in analysis. N. G. De Bruijn. New York, Interscience, 1958. 211 p. $5.75.

Nebraska symposium on motivation. 1958. Marshall R. Jones, Ed. Lincoln, Neb., University of Nebraska Press, 1958. 288 p. Current theory and research in motivation, v. 6.) $3.50; pap. $3.00. Another in the long series which serves as background for motivation in the choice of food.

ABSTRACTS

—Compiled by H. A. Campbell

BIOLOGICAL SCIENCES

Biochemistry

Effect of binding of ions and other small molecules on protein structure. IV. Two electrophoretically distinguishable types of interaction of bovine serum albumin with acidic media.

Cann, J. R. (Dept. of Biophys., Univ. of Colorado Med. Center, Boulder). *J. Am. Chem. Soc. 80,* 4263–4 (1958).

Bovine serum albumin undergoes 2 electrophoretically distinguishable types of interaction with acidic media. The first type of interaction is observed only in acetate-contg. media at relatively high protein concn., and is interpretable in terms of reversible complexing of the protein with undissociated buffer acid. The other type of interaction is best studied at low protein concn., although with proper choice of electrolyte compn. it can also be observed at high concn. This type of interaction has been interpreted by Aoki and Foster in terms of a pH dependent protein transformation.

Protein structural studies.

Turner, J. E. (Indiana Univ., Bloomington). *Dissertation Abstr. 19,* 435 (1958).

Protein structure was studied with regard to 1) peptide subunits bound together by disulfide bonds in protein molecules; 2) gamma-glutamyl residues in protein molecules; 3) the surface charge of some globular protein molecules. These results, along with data on protein-anion complexes, indicate that the serum globulins possess a negatively charged surface whereas the serum albumin molecule has a positively charged surface.

Thiolation of proteins.

Benesch, R. and Benesch, R. E. (Marine Biol. Lab., Woods Hole, Mass.). *Proc. Natl. Acad. Sci. 44,* 848–53 (1958).

N-acetylhomocysteine thiolacetone (AHTL) reacts smoothly with amino acids to form N-acetylhomocysteine peptides. The application of this reaction to the thiolation of proteins was limited by the fact that a relatively high pH and long reaction times were required to obtain good yields. It was now found that in the presence of Ag, the thiolation proceeds rapidly at room temp. in aq. soln. at pH 7.5. The Ag and AHTL react to form an insol. complex which, in turn, reacts with protein amino groups. A max. of 2 Ag^{+}/mole of AHTL is bound and one proton is liberated for each equiv. of silver.

A new method for the protection of thiol groups.

Pimlott, P. J. and Young, G. T. (The Dyson Perrins Lab., Oxford Univ., Engl.). *Proc. Chem. Soc.* 257–8 (1958).

A new method is reported for the protection of thiol groups, with special application to the synthesis of peptides contg. cysteine. By the action of benzylthiomethyl chloride, the thiol is converted into its benzylthiomethyl deriv. Such mercaptals are remarkably stable, but are smoothly cleaved by mercuric chloride, giving the mercaptide, from which the thiol may be regenerated.

Protein hydration and behavior.

Klotz, I. M. (Dept. of Chem., Northwestern Univ., Evanston, Ill.). *Science 128,* 815–21 (1958).

A variety of unique features of protein behavior are interpreted in terms of frozen water of hydration. Emphasis is placed on the role played by the solvent in fixing the structure and properties of the solute molecules, as well as the influence of the solute in imposing a structure on the solvent.

Interactions of tocopherol with proteins and amino acids.

Voth, O. L. and Miller, R. C. (Pennsylvania State Univ., University Park). *Arch. Biochem. Biophys. 77,* 191–205 (1958).

Interactions between tocopherol and bovine serum albumin and β-lactoglobulin have been studied over a wide range of pH values. The binding affinity for tocopherol is attributed to the over-all electrostatic charge of these proteins. Tocopherol appears to be bound to negatively charged centers. Data for free amino acid interactions with tocopherol support this conclusion. A mechanism of binding is proposed.

Complex phospholipids.

Collins, F. D. (Dept. of Biochem., John Curtin School of Med., Australian Natl. Univ., Canberra). *Nature 182,* 865–6 (1958).

This paper is concerned with the identification of new phospholipids in N-2:4-dinitrophenylated and methylated derivs. from sheep brain. The characteristics of the polar fraction obtained by countercurrent distribution in 85% aq. EtOH-light petroleum were studied using chromatography. A dinitrophenyl-contg. compd. isolated from this fraction was found to contain no free amino groups, no aldehydogenic groups and no sulfur. This complex phospholipid was thought to consist of one molecule of lysolecithin and one molecule of lysophosphatidyl ethanolamine joined together by a compd. contg. no phosphorus made up of 2 unidentified residues contg. nitrogen, sugar and a fatty ale. The presence of these materials in sheep brain indicates that similar complex phospholipids may account for some of the unidentified compds. contg. nitrogen that have been described in phospholipids in other tissues.

The use of furfural for the determination of acetone bodies in biological fluids.

Lyon, J. B. and Bloom, W. L. (Emory Univ., Atlanta, Georgia). *Can. J. Biochem. Physiol. 36,* 1047–56 (1958).

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A rapid and sensitive method for the detn. of acetone plus acetoacetate, and total acetone bodies in blood and urine is described. It is based upon the condensation of acetone and furfural in the presence of a strong base to form difurfurylidene-acetone, which develops a red to violet color in strong acid. The effective range is from 1 to 6 μg of acetone sample. The average standard deviation, based on recoveries of added material, was 5%. When the method was applied to detns. in blood and urine of several species, the results agreed with those reported by others.

Browning and the Amadori rearrangement.

NORDIN, P. AND KIM, Y. (Dept. of Flour and Feed Milling Ind., Kansas Agr. Expt. Stn., Manhattan). *J. Agr. Food Chem. 6*, 765–70 (1958).

The browning of glucose with alanine, glycine, and phenylalanine in soln. was compared with the browning of the Amadori rearrangement products of glucose and the corresponding amino acids. The rates of browning and the development of ultraviolet spectra for these systems were recorded. The amt. of Amadori rearrangement products formed in a browning system was measured.

Microbiology

Microbial and other enzymes as depilatory agents.

CONDON, T. C., JONES, H. W., CLARKE, I. D. AND NAGHSKI, J. (Eastern Regional Research Lab., Philadelphia, Penna.). *Appl. Microbiol. 6*, 293–7 (1958).

Studies with bacterial, fungal, and other enzymes revealed varying degrees of depilatory action. This activity could not definitely be correlated with the proteolytic or dextrinizing power as measured by hydrolysis of casein and starch.

Separation of bacterial spores by foam flotation.

BOYLES, W. A. AND LINCOLN, R. E. (Fort Detrick, Frederick, Md.). *Appl. Microbiol. 6*, 327–34 (1958).

A selective method of removing and/or concentrating bacterial spores and vegetative cells from the culture growth medium by foam flotation is described. Foaming chambers were made of simple glass cylinders equipped with spargers.

Nutrition

Weight control through prevention of obesity.

SEBRELL, W. H. (Williams-Waterman Fund, Research Corp., New York City). *J. Am. Dietetic Assoc. 34*, 920–3 (1958).

A discussion of the obesity problem and its causes with the suggestion that the real method of controlling it lies in education. The author suggests that the present educational trends in nutrition are only encouragements to eat more and better food without teaching that obesity is malnutrition and to be avoided as much as a deficiency in proper nutrients.

Metabolic demands as a factor in weight control.

POLLACK, T. AND CONSOLAZIO, F. (New York Univ. Post Graduate School of Med.). *J. Am. Med. Assoc. 167*, 217–19 (1958).

The importance of the caloric expenditure factor in the development of moderate obesity in the adult should not be minimized. It is important for persons to recognize that certain physiological changes take place in the human body that demand readjustment of the work and play habits or special attention to food intake. Small increments of excess dietary caloric intake and small decrements of decreased output of work together can be responsible for much adult obesity.

Climate and caloric intake.

Nutrition Revs. 16, 237–8 (1958).

Results of nutritional studies on young soldiers fail to indicate a major influence of ambient temp. on caloric requirements. Indirect factors, such as the increased work involved in wearing and performing duties in heavy protective clothing are responsible for most of the increased caloric requirements of cold climates. In arriving at an estimate of food requirements in the subarctic, knowledge of the type of work to be performed is more important than climate for individuals with adequate clothing and shelter.

Physiological and nutritional aspects of obesity.

MAYER, J. (Harvard Univ. School of Public Health, Boston, Mass.). *Borden's Rev. 19*, No. 3, 35–55 (1958).

There is little doubt that the prevalence of obesity in this country is on the increase and that it is accompanied by increased mortality from a number of degenerative diseases. There is also the likelihood that the relationship between obesity *sensu stricto*, (i.e. excess fat accumulation) and disease has been obscured by the fact that the insurance tables which provide the bulk of available data were established, not in terms of individual fat content, but in terms of weight. Body build *per se* shows correlation with certain diseases. In spite of these difficulties and complexities, it is still fair to say that the relationship of obesity and disease is close enough to allow obesity to be considered one of the most serious public health problems facing Western societies.

The chemistry of lipids as related to atherosclerosis.

ALVAREZ, W. C. *Geriatrics 13*, 694–5 (1958).

A discussion of a number of papers presented on the chemistry of lipids in which the following points were made by Dr. I. H. Page of the Cleveland Clinic. Not enough definite knowledge is available to indicate that physicians are justified in ordering drastic changes in the diets of patients. It may well be that the quality of fat in the diet is important, but other factors may be even more significant. It remains to be proved that long-term administration of a diet in which the usual 40% fat calories is reduced to 25% will elicit a significant and lasting reduction of plasma lipid levels. It is probably a good thing to cut down on the amt. of fat in the diet, and there is some evidence that it is wise to use vegetable instead of animal fats but no justification for a low cholesterol diet. What happens to a person's blood lipids and blood cholesterol is not detd. by the amt. of fat or type of fat he takes but by his body reaction to the fat.

Effect of β-sitosterol on regression of hypercholesterosis and atherosclerosis in chickens.

DILLER, E. R., WOODS, B. L. AND HARVEY, O. A. (Biochem. Research Div., Lilly Research Labs., Indianapolis, Ind.). *Proc. Soc. Exptl. Biol. Med. 98*, 813–17 (1958).

An elevated cholesterol concn. in the liver, serum, and aorta of the chicken was reduced by administration of β-sitosterol in presence or absence of dietary cholesterol or by the withdrawal of dietary cholesterol. Atheroma regression in the chicken was accomplished by the administration of β-sitosterol in presence of dietary cholesterol, this regression was paralleled by a drop in cholesterol concn. of the blood and liver.

Fat deposition in rat tibia due to lysine deficiency.

ROHDENBURG, E. L. (Stine Lab., E. I. du Pont de Nemours and Co., Newark, Del.). *Proc. Soc. Exptl. Biol. Med. 98*, 835–6 (1958).

Results with lysine-supplemented exptl. diets and with stock diets show that the lipid content of the tibia is relatively low when sufficient lysine for optimum growth is available to young rats. With the lysine-deficient diet, growth is retarded and bone lipids are increased. Interference with production of normal bone marrow appears to be a definite indication of lysine deficiency.

Supplementation of diets with proteins and amino acids.

FLODIN, N. W. (Lysine Div., E. I. du Pont de Nemours, Inc., Wilmington, Del.). *Am. J. Public Health 48*, 1315–22 (1958).

Methods of improving the protein efficiency of the human diet are discussed in the light of recent research. Emphasis is placed on the lysine supplementation of bread. Comments on the economic aspects of the problem are also included.

The amino acid adequacy of milo (grain sorghum) for the growth of rats.

POND, W. G., HILLIER, J. C. AND BENTON, D. A. (Dept. of Animal Husbandry, Oklahoma State Univ., Stillwater). *J. Nutrition 65*, 493–502 (1958).

Weanling male rats were used to study the effects of supplementing milo with amino acids. The addn. of 0.5% of L-lysine and 0.2% of DL-threonine to the basal ration produced growth approximately equal to that obtained with a purified diet contg. 11% of casein, but inferior to that obtained with a 21% casein purified diet. The addn. of 0.2 or 0.3% of DL-isoleucine, 0.05 or 0.10% of DL-methionine, 0.1% of DL-tryptophan or 0.2% of DL-valine had no effect on growth rate in any of the combinations used. Lysine and threonine are probably the most limiting amino acids in milo for growth.

Changes in intestinal bacterial flora and role of infection in kwashiorkor.

SMYTHE, P. M. (Dept. of Child Health, Univ. of Cape Town, South Africa). *Lancet 7049*, 725–7 (1958).

It is suggested that one effect of an inadequate protein diet is disturbance of the intestinal flora, and that this plays a significant part in the clinical picture of kwashiorkor. Better criteria of severity of kwashiorkor are needed. Muscle power, measured in a simple way, has been used as a criterion. The average gain in weight in a large series of cases could be more widely used in comparing the efficacy of different forms of treatment. The complicating effects of infection and possibly disturbed intestinal flora should be controlled as far as possible before comparing one dietetic regime with another.

Iron metabolism in protein deficiency.

Nutrition Revs. 16, 251–2 (1958).

Results of expts. performed with rats indicate that iron metabolism is severely deranged quite early in protein deprivation. All iron uptake is reduced by hematopoietic tissues. This may be due to a requirement for protein for normal iron transport, and the effects of protein deficiency on iron-contg. enzymes.

Dietary potassium supplementation and performance in the desert.

FREGLY, M. J. AND IAMPIETRO, P. F. *Metabolism: Clin. and Exptl. 7*, 624–34 (1958).

The effect of dietary K supplementation on performance has been studied in a desert environment. Performance ability was assessed by measurement of heart rates after a 4.5 mile hike in 2 hrs.; scores on the Harvard Step Test; electrocardiograms and morning rectal temps. Data presented indicates that performance may be carried out normally with a total K intake of 70–75 meq/day despite large sweat losses. Dietary supplementation to provide nearly twice this amt. did not influence performance.

Refractoriness to intrinsic factor.

Nutrition Revs. 16, 235–7 (1958).

Some pernicious anemia patients when treated with intrinsic factor concentrates prepd. from hog mucosa develop a refractory state which is manifested by a poor vitamin B_{12} absorption. Even after development of this state normal absorption of the vitamin can be achieved when gastric juice from normal human subjects is given.

Vitamin B_{12} metabolism in liver disease.

Nutrition Revs. 16, 230–1 (1958).

Patients with a diagnosis of liver disease were injected intramuscularly with 60 μg of vitamin B_{12}. These patients excreted much less B_{12} than did control patients. There was a good correlation between the degree of liver damage, as estd. by the standard laboratory tests, and the degree of reduction of B_{12} excretion. It is suggested that B_{12} excretion may be a better measure of liver damage than standard procedures.

Nutritional studies with the hyperthyroid rat.

Stevens, C. O. and Henderson, L. M. (Dept. of Chem., Univ. of Illinois, Urbana). *J. Nutrition 64*, 67–83 (1958).

Experiments designed to improve the assay for substance(s) in liver and other natural materials which partially reverse the growth suppression of hyperthyroid rats have been reported. Cholesterol, corn oil or cryst. aureomycin stimulated growth slightly under these assay conditions. A combination of these 3 substances supported growth and survival nearly equiv. to that obtained by removing the iodinated casein from the diet. Casein and many other proteins or protein-contg. supplements were not active. Removal of iodinated casein from the diet lowered the basal metabolic rate and caused immediate resumption of growth. A liver residue active in stimulating growth did not alter the basal metabolic rate.

Alcohol and nutritional diseases of the nervous system.

Victor, M. (Massachusetts General Hosp., Boston, Mass.). *J. Am. Med. Assoc. 167*, 65–70 (1958).

Nutritional disorders assume considerable importance by virtue of the serious and often permanent damage which they inflict on the nervous system particularly on the mind. The specific nutritional factor concerned is thiamine. Disease, however, may result from a deficiency of any one of 3 B vitamins: thiamine, pyridoxine, or pantothenic acid.

Dietary treatment of myopia in children.

Gardiner, P. A. *Lancet 7031*, 1152–5 (1958).

In a group of shortsighted children who received extra animal protein, the rate of visual deterioration was much less than in a group whose diet was not changed. Of the children over 12, there was actual improvement in most of those who took the greatest quantity of animal protein.

FOOD AND FOOD TECHNOLOGY

Baking and Bakery Products

The physical chemistry of wheat proteins in connection with the baking value of flours.

Bloksma, A. H. (Inst. of Cereals, Flour and Bread T.N.O., Wageningen, The Netherlands). *Wallerstein Lab. Commun. 21*, 215–30 (1958).

This review deals with the explanations that have been proposed for the differences in the properties of gluten from distinct lots of wheat or flour and for the effect of flour improvers. An outline of some methods used for the investigation of the mechanical properties of doughs is presented. The amino acid compn. of gluten is reported. The following sections deal with 4 types of chem. bonds which might det. the rheological properties of the gluten, the peptide bonds, disulfide cross linkages, hydrogen bonds and electrostatic forces. Some remarks on the interaction between proteins and lipids in the dough are also included.

Beverages

Process and apparatus for preparing carbonated liquids.

Konig, F. U. S. 2,855,307. Oct. 7, 1958.

Provides for one step in a process for preparing a homogenized carbonated liquid. A jet of carbonic acid and a jet of a liquid to be carbonated are slanted toward each other so as to unite on a surface area, thus causing joint atomization of the jets.

Cereals and Grains

The effect of freezing on the hydration characteristics of rice.

Roseman, A. S. (Southern Regional Research Lab., New Orleans, La.). *Food Technol. 12*, 464–8 (1958).

Milled and unmilled rice when gelatinized and then frozen in the presence of 60% or more water in the grain underwent structural alteration. The dried treated grains were chalky-white, uniformly spongy, and hydrated quite rapidly with water at room temperature. Slow freezing or fast freezing followed by a slow thaw appear to be required for this alteration. Alteration of properties by this process could be inhibited by freezing in the presence of calcium nitrate, a swelling agent.

Coffee and Coffee Products

Phenolic acids in coffee.

Lentner, C. and Deatherage, F. E. (Dept. of Agr. Biochem., Ohio State Univ., Columbus). *Chem. and Ind. 41*, 1331–2 (1958).

Analysis of the "isochlorogenic band" obtained by partition chromatography on silica gel of hot exts. of ground coffee beans showed the probable presence of isomers of chlorogenic acid. Results regarding these isomers agree with the recent identification of chlorogenic acid, isochlorogenic acid, neochlorogenic acid and compound "510", a further caffeic acid ester, in coffee. In addition at least 2 esters of ferulic acid and one ester of *p*-coumaric acid have been tentatively identified. There was some indication that the alcoholic moiety of these compds. is quinic acid. Other phenolic compds. were detected in green and especially in roasted coffee, but have not been identified.

Dehydration

Rapid vacuum freeze-drying of meat.

Brynko, C. and Smithies, W. R. (Defense Research Med. Labs., Toronto, Can.). *J. Sci. Food Agr. 9*, 576–83 (1958).

Freeze-drying carried out in conventional equipment is a slow process, the rate of drying being limited by the rate of transfer of heat of sublimation. A method is described to carry out rapid freeze-drying of meat or other foodstuffs by laying the pieces between heater plates fitted with metal spikes which conduct heat uniformly and efficiently into the material. Meat slices ¾ in. thick can be freeze-dried in 3–5 hours.

Fats and Oils

The specific distribution of fatty acids in the glycerides of animal and vegetable fats.

Mattson, F. H. and Lutton, E. S. (Procter and Gamble Co., Miami Valley Labs., Cincinnati, Ohio). *J. Biol. Chem. 233*, 868–71 (1958).

By means of pancreatic lipase, which specifically removes the fatty acids esterified with the primary hydroxyl groups of glycerol, the location of the fatty acids in the glycerides of a number of naturally occurring vegetable and animal fats has been studied. Naturally occurring triglycerides exhibit a high degree of specificity of fatty acid distribution, so that random distribution does not occur in either vegetable or animal fats. In the vegetable fats the satd. fatty acids are predominantly esterified with the primary hydroxyl groups of glycerol. Lard is unique in that of all the fats studied, it is the only one in which the satd. fatty acids are predominantly in the 2 position.

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MEMBERSHIP

Write to nearest regional secretary if within an area covered by a regional section, or to the Executive Secretary of the Institute for an application form and information regarding qualifications and classifications.

Fish

The use of fish flours as human food.

ANON. (Nutrition Div., FAO of the U.N., Rome, Italy). *Proc. Nutrition Soc. 17*, 153–60 (1958).

Fish flour, properly processed, would be an excellent dietary supplement in areas of the world where protein malnutrition is prevalent. This review covers such topics as acceptability criteria, methods of manufacture and recent international acceptability surveys. A summary of anal. data is also presented.

Legislation

The federal food, drug and cosmetic act of the United States.

DUNN, C. W. *Food Drug Cosmetic Law J. 13*, 407–68 (1958).

The safe food additives law and its amendment were surveyed in a symposium held by the International Commission for Agricultural Industries in Paris, France. Lists of approved and unsatisfactory chemical additives and of pesticides tolerances established by the FDA are presented in addition to legal standards of particular interest to the meat packing industry.

Starch

Manufacture of filaments, films or the like from natural proteinaceous material.

MCDOWELL, C. J. Assignor to Corn Products Refining Co. U. S. 2,854,345. Sept. 30, 1958.

After heating at 60° C., washing and decanting, a slurry of spray dried corn gluten is dispersed in an alk. soln. (pH 10.5–11.5), filtered and then deaerated. The resulting translucent soln. is spun into filaments, which are stretched, cured and finally baked.

Miscellaneous

Planning your research paper.

SANFORD, F. B. (Fishery Technological Lab., Seattle, Wash.). *Fishery Leaflet No. 447*, U. S. Dept. of Interior, Fish and Wildlife Service (April 1958); *Comm. Fisheries Abstr. 11*, 15 (Oct. 1958).

This manual, which is divided into 2 main sections, presents suggestions on how to plan your research paper. The first section deals with preliminary steps in planning—such as outlining, choosing headings, and making tables. The second section deals with the various parts of the research paper: title, abstract, table of contents, introduction, acknowledgment, procedure, results and discussion, conclusions, summary, and literature cited. The difference between the conclusion and the summary is made clear, and the relationship between the title and the specific objectives listed in the introduction is pointed out. Finally, a way of avoiding repetition in writing the summary and the abstract is suggested.

PHYSICAL RESEARCH

The problem of polymer coacervation.

BRODA, A. AND CHODKOWSKA, M. B. (Inst. of Synthetic Fibers, Lodz, Poland). *J. Polymer Sci. 30*, 639–44 (1958).

The relationship between concn. of polymer in the pptd. phase and the properties of the system are derived. This relation indicates that, for any polymer, a sepn. into 2 liquid phases which agrees with Kruyt's definition of coacervates can be obtained. It is suggested that it is not always correct to distinguish coacervation as a special phenomenon. The exptl. results of investigation of the systems: ethanediol-water-phenol-polyamide and acetone-methanol-benzene-polystyrene are presented.

Industry Publications

Neumann-Buslee and Wolfe, Inc., 5800 Northwest Highway, Chicago 31, Illinois, has recently issued a new **Catalog and Price List of Essential Oils** and related products. A complete revision in make-up will enable the trade to use this book with greater facility. The new catalog will be issued four times per year, with each issue carrying a new color scheme to enable the trade to distinguish the most recent issue. Simultaneously, a colorful new label is being used for all Neumann-Buslee and Wolfe products, having undergone modernization with a view to better identification and greater legibility of product named.

Industry

PERSONNEL

Dr. Maurice Bender has transferred from the fishery products inspection and certification unit of the U. S. Bureau of Commercial Fisheries to the Division of General Medical Sciences at the National Institutes of Health. He will be concerned with administration of the research grants program of the Division.

Dr. Gideon E. Livingston, associate professor of food technology at the University of Massachusetts, director of Food Science Associates, food industry consultants, and executive secretary of Phi Tau Sigma, the food science honor society, leaves Amherst, Massachusetts, to join the Continental Baking Company in Rye, New York. Dr. F. M. Sawyer of the University of Massachusetts succeeds Dr. Livingston as executive secretary of Phi Tau Sigma.

G. E. Livingston

Mrs. Robert Meyner, wife of New Jersey's Governor, is seen here receiving a gift during ceremonies dedicating the opening of a new H. Kohnstamm & Co. plant in Kearny, New Jersey. The gift, containing a collection of Kohnstamm products, is being presented by Dr. David Jorysch, Technical Director of the Kohnstamm flavor division. Also seen are: left, Governor Meyner, who was guest of honor at the opening ceremonies, and, behind Mrs. Meyner, Paul L. Kohnstamm, President of the chemical concern.

Dr. Albert L. Elder, director of research of the Corn Products Company, Argo, Ill., and an authority on medicinal chemicals, proteins, and starches, has been chosen president-elect of the American Chemical Society. He will head the Society in 1960. Dr. Elder, an IFT member of long standing, was elected in a nationwide mail ballot of the Society's 86,000 chemists and chemical engineers. At the same time, Dr. Byron Riegel, director of chemical research and development of G. D. Searle & Co., Chicago, was elected to the Society's Board of Directors for a three-year term as a Regional Di-

rector. Dr. Louis P. Hammett, professor of chemistry at Columbia University, was re-elected a Regional Director.

Dr. Elder, the new president-elect, was head chemical advisor of the War Production Board and coordinator of the penicillin program in World War II. He directed the construction and coordination of 20 plants for the production of penicillin in the United States and Canada. He also was closely associated with the early development of the Government's synthetic rubber program, and represented the Patent Office War Division on the War Production Board.

He was president of the Research and Development Associates of the Quartermaster Food and Container Institute from 1951 to 1953, and chairman of the committee on foods of the National Research Council Quartermaster Advisory Board from 1954 to 1957. For "service, loyalty and devotion to duty" from 1944 to 1957, he received the Award of Appreciation of the Quartermaster Food & Container Institute. He is the author of several scientific articles and three textbooks on chemistry.

A native of Lexington, Ill., Dr. Elder received the B. A. degree in 1923, the M.S. in 1925 and the Ph.D. in 1928 from the University of Illinois. After two years as Charles M. Hall Research Instructor at Oberlin College, he joined the faculty of Syracuse University in 1930. He was professor of chemistry there until 1941, when he left to serve the War Production Board.

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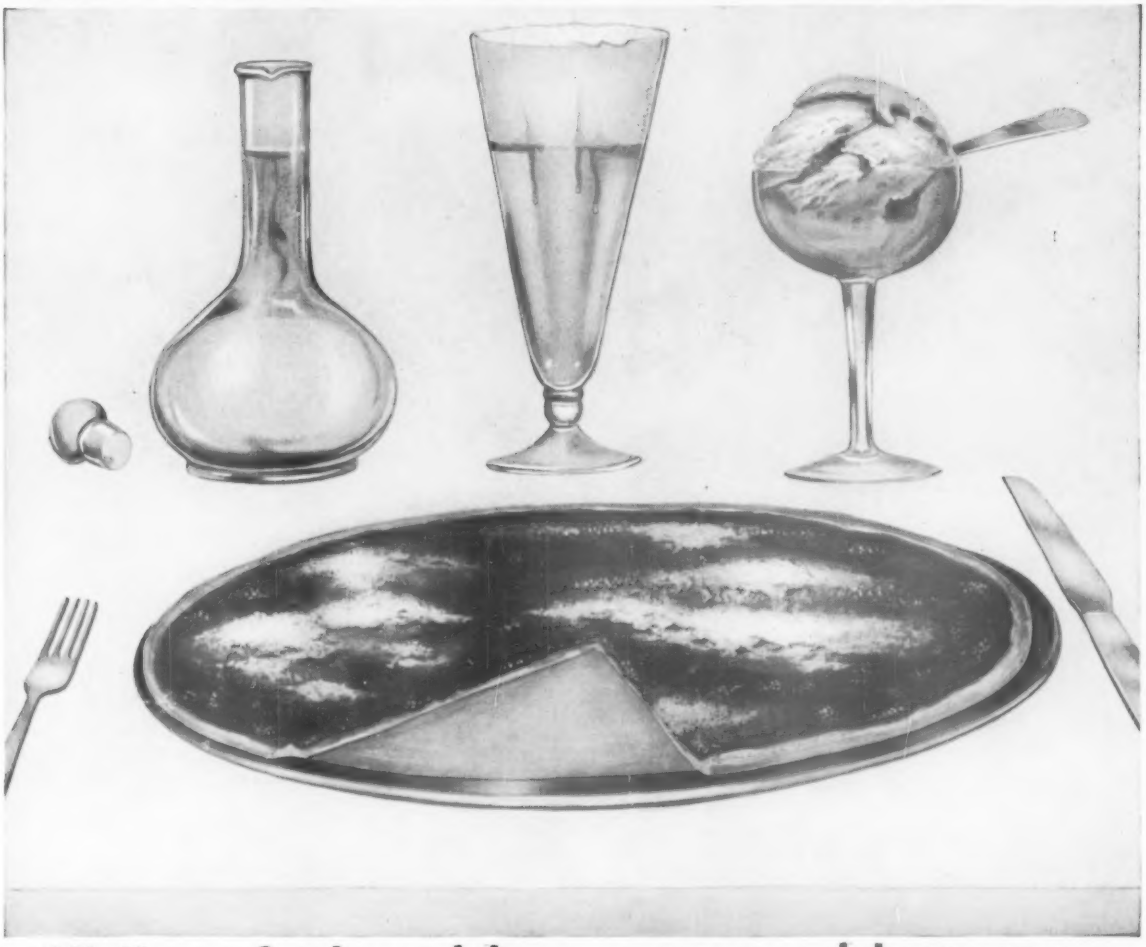

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